AD-A152 735 PRESENTATIONS AT THE TRI-SERVICE CLOUD MODELING WORKSHOP (2ND) HELD AT TH..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA E BAUER AUG 84 IDA-M-9-VOL-1 1/7

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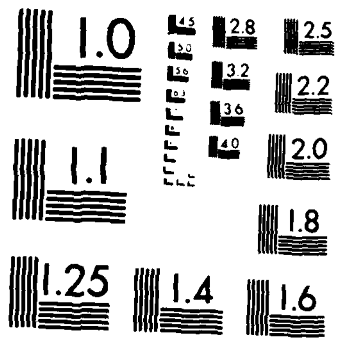
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AD-A152 735

IDA MEMORANDUM REPORT M-9

PRESENTATIONS AT THE SECOND TRI-SERVICE CLOUD MODELING WORKSHOP

HELD AT THE NAVAL SURFACE WEAPONS CENTER, WHITE OAK, MARYLAND 26-27 JUNE 1984

Volume I

Ernest Bauer, *Editor*

August 1984

APR 3 1985

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Prepared for
Defense Advanced Research Projects Agency

IDA

INSTITUTE FOR DEFENSE ANALYSES
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

clouds, cloud-free line-of-sight, space-based laser, clutter, background, surveillance, infrared search & track (IRST), cirrus, cumulus, cloud climatology.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Second Tri-Service Cloud Modeling Workshop was held at Naval Surface Weapons Center, White Oak, MD, on 26-27 June 1984. Presentations were made on the current status of cloud data and cloud impact models and on needs for a variety of DoD applications. This document presents briefing charts for the presentations and related introductory and summarizing material. The preparation of this document was supported by DARPA/DEO.

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Volume I

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INSTITUTE FOR DEFENSE ANALYSES

Contract MDA 903 84 C 0031
DARPA Assignment A-88

PREFACE

On 26-27 June 1984 the Second Tri-Service Cloud Modeling Workshop was held at the Naval Surface Weapons Center, White Oak, MD.

The purpose of the meeting was the exchange of information between users of cloud data information, representing the developers of electrooptical surveillance (and other) systems, and the producers of cloud information in the DoD weather community.

This document summarizes the results of the workshop and related work. Part I consists of the DoD letter establishing the Tri-Service Cloud Modeling Effort, the letter of invitation and program of the meeting, and a brief summary report. Part II consists of the briefing charts and supplementary material - classified material is included as a supplementary volume. Part III consists of the list of invitees and Part IV of the list of attendees, while Part V consists of supplementary comments received after the meeting, which serve to expand on the summary report. Finally, Part VI summarizes a related meeting held at IDA on 24 January 1984 on the use of airborne lidars to collect meteorological data.

The preparation of this document was supported by DARPA/DEO under IDA Task A-88. The material contained herein is presented for the use and convenience of interested parties. It has not been evaluated, analyzed, or subjected to IDA review.

SUMMARY

The Second Tri-Service Cloud Modeling Workshop was held at the Naval Surface Weapons Center, White Oak, Maryland, on 26-27 June 1984.

Clouds affect DoD systems--high-energy laser weapons systems, optical surveillance systems and some others--in a wide variety of ways. These cloud effects are at times not well understood and even more frequently not well described. Indeed, there is a major gap between the existence of cloud data and its utilization for the realistic evaluation of DoD weapons systems performance. To quote from the DoD letter establishing the Tri-Service CMW (see p. 3 for the full letter):

> "The realistic evaluation of DoD weapon system performance is a critical element of the multimillion/billion dollar acquisition decisions. The weather limitations on the performance must play a key role in the evaluation process.
>
> "We (DoD meteorologists) have worked very hard to obtain recognition of the weather effects by the operational evaluation community; however, now that we have achieved this recognition, we are failing to produce even the most basic binary cloud data and methodologies needed to support the evaluation programs."

In view of this recognized deficiency, the purpose of the Tri-Service Cloud Modeling Workshop is the exchange of information between users of information on clouds, representing the developers of a variety of DoD systems, and the producers of cloud information in the weather community.

The work reported herein falls into several broad categories, namely:

- Data bases and their limitations--see pp. 67, 249, 517, 537, 569, 599, 627

- Cloud models--see pp. 17, 45, 119, 323, 377
- Cloud description (small and large scale)--see pp. 145, 201, 311, 353, 417, 471, 501, 613, C-1*
- System needs--see pp. 83, 135, 685, C-22*
- System applications--see pp. 99, 199

The following general comments can be made:

1. The meeting provided a forum for systems users (however defined) to learn what kinds of cloud data exist and how related problems are being addressed, for systems analysts to report on how they use cloud data, and for the people who generate the data to see what kind of questions are being asked.
2. There was an exchange of information with non-DoD agencies, with presentations made by NASA and NOAA (see pp. 537, 569).

A brief report by the steering committee which discusses some outstanding technical problems is given on p. 11. The generic problem of the lack of adequate interaction between cloud users and cloud developers which led to the establishment of the Tri-Service Cloud Modeling Workshop is still in evidence; it can be mitigated by actions on the part of the steering committee, which must actively seek a balance in terms of stronger user representation, and also serve as a focus on cloud data bases and methodologies for users. To achieve these actions requires explicit support.

*See classified supplementary volume.

CONTENTS

PART I

OFFICE OF THE UNDER SECRETARY OF DEFENSE

WASHINGTON DC 20301

RESEARCH AND ENGINEERING

10 August 1982

MEMORANDUM FOR DIRECTOR OF LABORATORIES, HEADQUARTERS AIR FORCE SYSTEMS COMMAND

SUBJECT: Cloud Models for Realistic Evaluation of DoD Weapon System Performance

This is to request some assistance in providing planning guidance for a tri-Service initiative to improve meteorological support for the DoD performance evaluation activities.

The realistic evaluation of DoD weapon system performance is a critical element of the multimillion/billion dollar acquisition decisions which must often be made by DoD. The weather limitations on the performance of weapon/sensor systems must play a key role in the evaluation process. Utility/engagement models and war gaming models all need realistic weather models to handle the historical/climatological data needed to insure realistic and relevant results. Therefore, the meteorological community must be prepared to support the operational evaluation, acquisition, studies and analysis, and war gaming communities with the historical data bases, methodologies and computer programs which can efficiently interact with the system performance models to produce the needed realistic output.

We have been working to adequately address the clear air atmospheric transmission problems with some success, but still have major difficulties handling cloud data effectively and efficiently, especially in support of the evaluation of systems needing a cloud-free line-of-sight (CFLOS) or cloud-free field-of-view (CFFOV) for successful operations. We have worked very hard to obtain recognition of the weather effects by the operational evaluation community; however, now that we have achieved this recognition, we are failing to produce even the most basic binary cloud data and methodologies needed to support the evaluation programs. We need to pull together now and resolve some of the recurring issues in cloud modeling (temporal and spatial distribution not microphysical modeling). This includes identifying the complementary efforts by various organizations needed to achieve the goal of a DoD accepted cloud modeling methodology and data base to support DoD performance evaluation and war gaming activities. In addressing systems like Trident, Pershing, or MX; Copperhead, GBU-15 or Harpoon; space based laser, laser communications or HEL and all the follow-on systems, the meteorological community must be prepared to support the performance evaluation models supporting the acquisition of these systems.

In view of the above, I would like the Air Force Geophysics Laboratory to take the lead and work with the Naval Environmental Prediction Research Facility and the Engineer Topographical Laboratories to form a tri-Service planning group to 1) identify the key issues to be resolved, 2) outline the work needed, 3) discuss methods for achieving the goal, 4) identify agencies best able to provide solutions, and 5) draft a charter which would cover these key issues and provide for continuing group activities until the tasks are completed. While related to the current DARPA sponsored CFLOS project, the DoD-wide effort I am initiating is intended to be broader and of longer duration to insure advances are obtained to support many types of DoD systems affected by clouds. I would very much appreciate your support and assistance in achieving this goal of a DoD accepted cloud modeling methodology and data base to support the performance evaluation and war gaming activities of DoD. The initial planning meeting should be held within 60 days.

Edith W. Martin
Deputy Under Secretary of Defense
for Research and Engineering
(Research and Advanced Technology)

cc: Dr. McClatchey
LtCol Pfeffer
Col. Ramsay
LtCol Christensen
Dr. Bauer
Maj. Tomlinson

DEPARTMENT OF THE AIR FORCE
AIR FORCE GEOPHYSICS LABORATORY (AFSC)
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731

REPLY TO ATTN OF: AFGL/LYT 12 Mar 84

SUBJECT: Second Annual Tri-Service Cloud Modeling Workshop

TO: Distribution List

Dear Colleague

1. This is an announcement and a call for papers for the Second Annual Tri-Service Cloud Modeling Workshop, which will be held at the Naval Surface Weapons Center, White Oak, MD on 26-28 June 1984.

2. The first workshop, held at IDA in June 1983, was attended by about 80 representatives of the three Services, Universities, and Industry. The presentations from that workshop are contained in IDA Record Document D-16 (Vol. I Unclassified, Vol. II Secret) and is available to Government Agencies by request through Dr. E. Bauer, IDA (Institute for Defense Analyses, 1801 N. Beauregard St., Alexandria, VA 22311), and to others by request through DARPA.

3. The workshop to be held 26-28 June 1984 will emphasize Government needs for cloud modeling and will examine those techniques, methodologies, and data bases that are available, or under development, which can be used in evaluating cloud impacts on DoD systems. We are therefore calling for presentations in the following subject areas:

a. Cloud data requirements for high-energy laser weapons systems, surveillance, IRST, communication systems, etc.

b. Cloud modeling techniques including simulation, small-scale structure, IR backgrounds, cloud edge effects, cloud-free line of sight, etc.

c. Cloud data bases which may be available or applicable to the CLOUDS program, such as global data bases (3D/RT NEPH, International Satellite Cloud Climatology Program, etc.), and regional or climatic data bases.

4. Please submit unclassified abstracts in sufficient detail (200-400 words) to provide reviewers with a basis for comparison and acceptance. Indicate in your abstract the classification of the presentation, time requirements and the need for special projection facilities. Please send abstracts to Donald D. Grantham, AFGL/LYT, Hanscom AFB, MA 01731 by 20 April 1984. Authors will be notified of the presentations by 18 May 1984.

5. The overall classification of this meeting will be Secret/No Foreign Nationals. Clearances should be sent to Visitor Control, Security Office, Institute for Defense Analyses, 1801 N. Beauregard St., Alexandria, VA 22311 (Tel. (703) 845-2290 or AV289-2063) by 15 June 1984. The visit request should specify that the purpose is to attend the 2nd Tri-Service Cloud Modeling Workshop.

6. A Record Document will be prepared and distributed as soon as possible after the meeting. Speakers are asked to bring reproducible copies of their vugraphs and a title/abstract page to the meeting.

7. Arrangements have been made to provide time and facilities for Government Technical Direction meetings and reviews before and after the Workshop. If your agency would like to take advantage of these arrangements, please contact me (AV478-2982 or (617) 861-2982).

Sincerely

DONALD D. GRANTHAM
Chief, Tropospheric Structure Branch
Atmospheric Sciences Division

DEPARTMENT OF THE AIR FORCE
AIR FORCE GEOPHYSICS LABORATORY (AFSC)
HANSCOM AIR FORCE BASE, MASSACHUSETTS 01731

REPLY TO ATTN OF: LYT/(617) 861-2982/AV 478-2982 — 31 May 1984

SUBJECT: Second Tri-Service Cloud Modeling Workshop, 26-28 June 1984

TO: Distribution (Ref Atch to AFGL Ltr 12 Mar 84)

1. Based on the enthusiastic response to our 12 March 1984 call for papers for the subject Workshop, we have developed the enclosed tentative agenda. In general, presentation times will be 20 minutes including discussion. The few exceptions to this time limit have been notified individually. The Workshop will be held at the Naval Surface Weapons Center in the Auditorium of the Administration Building (see NSWC enclosure) beginning at 0830 each day.

2. The overall classification of the Workshop will be Secret/No Foreign Nationals. Security clearances are being handled through IDA. If you have not yet submitted your clearance, please send it to Visitor Control, Security Office, Institute for Defense Analyses, 1801 N. Beauregard St., Alexandria, VA 22311 (Telephone (703) 845-2183) by 15 June 1984, noting that it is for attendance at the Tri-Service Cloud Workshop at NSWC. If you have a current security clearance at IDA, please either write or phone the Security Office to notify them that you will be attending the Tri-Service Cloud Modeling Workshop.

3. A record document will be prepared and distributed as soon as possible after the meeting. Speakers are asked to bring reproducible copies of their vugraphs and a title/abstract page to the Workshop.

4. NSWC White Oak does not have military quarters available. Those traveling on military orders may pick up a Certificate of Non-Availability of Quarters from the Travel Office located in the Administration Building. A list of motel accommodations is included on the enclosed map showing their locations with respect to NWSC White Oak. Their will be no bus transportation provided between motels and NSWC; therefore, car rentals may be desirable.

5. Coffee and doughnuts will be available each morning. Lunches will be available in the Administration Building cafeteria. Plans are being made for an informal (beer and soda) party from 1700-1830 on 26 June.

6. The Cloud Modeling Workshop will conclude on Wednesday, 27 June with a Wrap-up Session at 1500-1600. Immediately following the Wrap-up, Dr. Ernie Bauer, IDA, will introduce an extra topic on Nuclear Winter that may be of interest to many of the workshop attendees. A Topical Review on this subject will be held the next morning, 0830-1200 Thursday, 28 June 1984.

Donald D. Grantham

DONALD D. GRANTHAM
Chief, Tropospheric Structure Branch
Atmospheric Sciences Division

3 Atchs
1. Agenda
2. NSWC Admin Bldg
3. NSWC Area Map

SECOND TRI-SERVICE CLOUD MODELING WORKSHOP

26-28 June 1984

Naval Surface Weapons Center
Administration Building Auditorium
White Oak, Silver Spring, Maryland

AGENDA

Tuesday, 26 June 1984

Session I - Workshop Overviews, 0830-1000 - Dr. Bernard Kessler, NSWC, Session Chairman

NSWC Welcome - Capt. J. J. Brannan, USN, Officer in Charge, White Oak

CLOUDS Program - Lt. Col. Vernon Bliss, AFWL

Cloud Model Methodologies, Overview and Caveats - Donald D. Grantham, AFGL

Cloud Data Bases, Overview and Caveats - James Bunting, AFGL

Session II - Cloud Model Applications, 1020-1230 - Dr. Paul Twitchell, Naval Air Systems Command, Session Chairman

* "DARPA's Interest in Cloud Data," David Zimmerman, PRA

* "Evaluation of the Effect of Clouds on SBL Applications," Ronald J. Nelson, SAI

** "Effect of Cloud Clutter on Target Detection," James L. Griggs, Jr., SAI

"Current Cloud Modeling Efforts at the Naval Environmental Prediction Research Facility, Paul M. Tag, NEPRF

* "Trident Targeting and Test Flight Analyses," Susan Masters, NSWC

** "Cloud Effects on Surveillance from Space and High Altitudes," Ernest Bauer and Hans Wolfhard, IDA

Session III - Cloud Models for IRST Applications, 1330-1700 - Dr. Elton Avara, ASL, Session Chairman

"Synthetic Cloud Scenes for IRST Sensor Design Applications," Alex T. Maksymowicz, Lockheed, and John H. Allen, SRI

"IR Radiative Properties of Cirrus and Cumulus Cloud and IRST System Application," G. Gal and T. Winarske, Lockheed

"Infrared Cloud Backgrounds and Sensor Performance," W.J. Tropf, A.N. Vareck, Johns Hopkins U., B.P. Sandford, J.H. Schummers, AFGL, and J. Schroeder, ONTAR

"The Navy Background Measurement and Analysis Program (BMAP), FY84," Bernard V. Kessler, NSWC

"An Empirical Cloud Model for SWIR and LWIR Pass Bands," Mike Scarborough and Robert A. Pilgrim, Teledyne Brown

*Paper classified SECRET. Briefing charts included herein are UNCLASSIFIED.

**Paper and briefing charts classified SECRET. These papers are presented in Volume II.

Wednesday, 27 June 1984

Session IV - Cloud Model Methodologies, 0830-1100 - Dr. Roland Nagel, NEPRF, Session Chairman

"Assessment of the LOWTRAN6 Cirrus Model," John Hornstein, NRL

"Profiles of Optical Extinction Coefficients Calculated from Droplet Spectra Observed in Marine Stratus Cloud Layers," V. Ray Noonkester, NOSC

"Interactive Software for Calculating Cloud-Free Intervals," Lt. Col. Vernon Bliss, AFWL

"3-D Cloud Simulation using the Sawtooth Model," Irving I. Gringorten, AFGL

"Correlation Functions for Cloud Cover and Ceiling," Ralph Shapiro, SASC

"Cloud and Visibility Modeling of Joint Mesoscale Probability in Central Europe," Oskar M. Essenwanger, US Army Missile Command

"The PRA Synthetic Cloud Scenes," Edward J. Stone, NRL

Session V - Cloud Data Bases, 1100-1230/1330-1445 - L/C Ed Tomlinson, AWS, Session Chairman

"The Real-Time Nephanalysis (RTNEPH)," Maj. S. Cox, AFGWC

"Cloud Data Bases from the International Satellite Cloud Climatology Project (ISCCP)," Herbert Jacobowitz, NOAA

"Multi-Year Global Cloud Data Set From NIMBUS-7 Satellite, P.H. Hwang, NASA, L.L. Stowe, NOAA, and P.K. Bhartia, SASC

"Viewing Angle Bias in Cloud Climatologies," James Bunting, AFGL

"Digital Imaging and Analysis from Cloud Climatology Data," T. Vonder Haar and T. Brubaker, CSU

"A New Data Base of Cloud Variables at Subfreezing Temperatures," Richard K. Jeck, NRL

Session VI - Workshop Wrap-Up, 1500-1630 - Panel: Dr. B. Kessler, Dr. E. Bauer, L/C V. Bliss, Dr. Elton Avara

Thursday, 28 June 1984

TOPICAL REVIEW - "Cloud Physical Aspects of Nuclear Winter" - Dr. Leon Wittwer, DNA, Chairman

"The Smoke Plume Rise and Scavenging Problems," Ernest Bauer, IDA**

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*Paper classified SECRET. Briefing charts included herein are UNCLASSIFIED.

**Copies of the briefing are available on request from IDA.

Subject: Report on the Second Tri-Service Cloud Modeling Workshop, 26-27 June 1984

From: Steering Committee: D. Grantham (Chairman), E. Avara, E. Bauer, P. Twitchell

This is a maturing specialty meeting, as can be seen in the historical context:

Oct. 1981	Initial Space-Based Laser (SBL) meeting. Presentations by systems analysts and meteorologists, but no bottom line.
June 1982	SBL- first presentation of Zero-Order Assessment (see IDA B-6*, Feb. 83). Things are beginning to jell. Col. Try sees the need for a coordination process which led to Dr. Edith Martin's Aug. 82 letter. Copy attached.
Nov. 1982	Tri-Service Cloud Modeling Workshop planning meeting at AFGL, which is Lead Lab. (see D-16**, p. 9).
June 1983	First Tri-Service Meeting at IDA. 152 invitees, 72 attendees. Successful, but too big for IDA- next meeting at NSWC (B. Kessler, host).
June 1984	Second Tri-Service Meeting at NSWC. 300 invitees, 95 attendees. Third meeting will be held at AFGL in May 1985, back-to-back with Atmospheric Transmission Conference.

This has been a successful program initiation by DARPA (STO and DEO), OUSDRE, and IDA. The attendance at the meetings, quality of presentations, discussion and overall interest in the topic shows that it fills a need, but it is clearly time to integrate the meeting with the Atmospheric Transmission Conference. While funding in the CLOUDS area is still inadequate, some funding is becoming available as the utility of the work is getting recognized.

*IDA Annotated Briefing B-6, "Cloud Effects on Space-based Laser Weapons Systems," E. Bauer et al., February 1983.

**IDA Record Document D-16, "Presentations at the Tri-Service Cloud Modeling Workshop held at IDA, June 1983," E. Bauer, Editor, July 1983.

The biggest deficiency of the June 1984 meeting was clearly the lack of user presentations listing needs, and this was recognized during the wrapup session. We call for a survey of users' needs and a marketing effort overseen by the steering panel.

(Recall that the CLOUDS program concept was designed to start with users' needs, which call for tailored output to use designated approaches to process/utilize relevant meteorological data. This concept of a customer-driven program as developed by the original steering group clearly remains valid and needs implementation).

Technical issues addressed in the discussion include the following:

1. RV issues- if it is a problem, it should be significant for both USAF and USN

2. Interaction between military and civilian agencies (e.g., ISCCP) should be encouraged, and available data should be advertized for all relevant users.

3. Important objects of the meeting include both critical review of existing work (e.g., CFLOS, cloud radiation models/data, cirrus models/data (e.g., LOWTRAN 6 Cirrus)) and the avoidance of duplication (e.g., in model development)

4. As now constituted, the steering group represents scientists/developers rather than users who have requirements and funding. This is a fundamental weakness which must be rectified if the Tri-Service Workshop is to be successful.

5. Cirrus is clearly an area which is ripe for development.

6. Small-Scale Structure needs emphasis:
   (a) what is needed?
   (b) how should data be analyzed/processed?
      (PSD vs third differences, Sobel transform, etc.)
   (c) what are the data? (how sharp are edges and structure at different wavelengths? - see, e.g., Z. G. Sztankay's letter in Part V.

7. Validation of models used by systems analysts: the meteorological community will always be unhappy with the data and models used, but will get system development funds only if they can show that the difference is critical. Typically, Lab Director's funds and other 6.1 and 6.2 money will have to be used to address validation- a vague feeling of unhappiness won't extract system development funds.

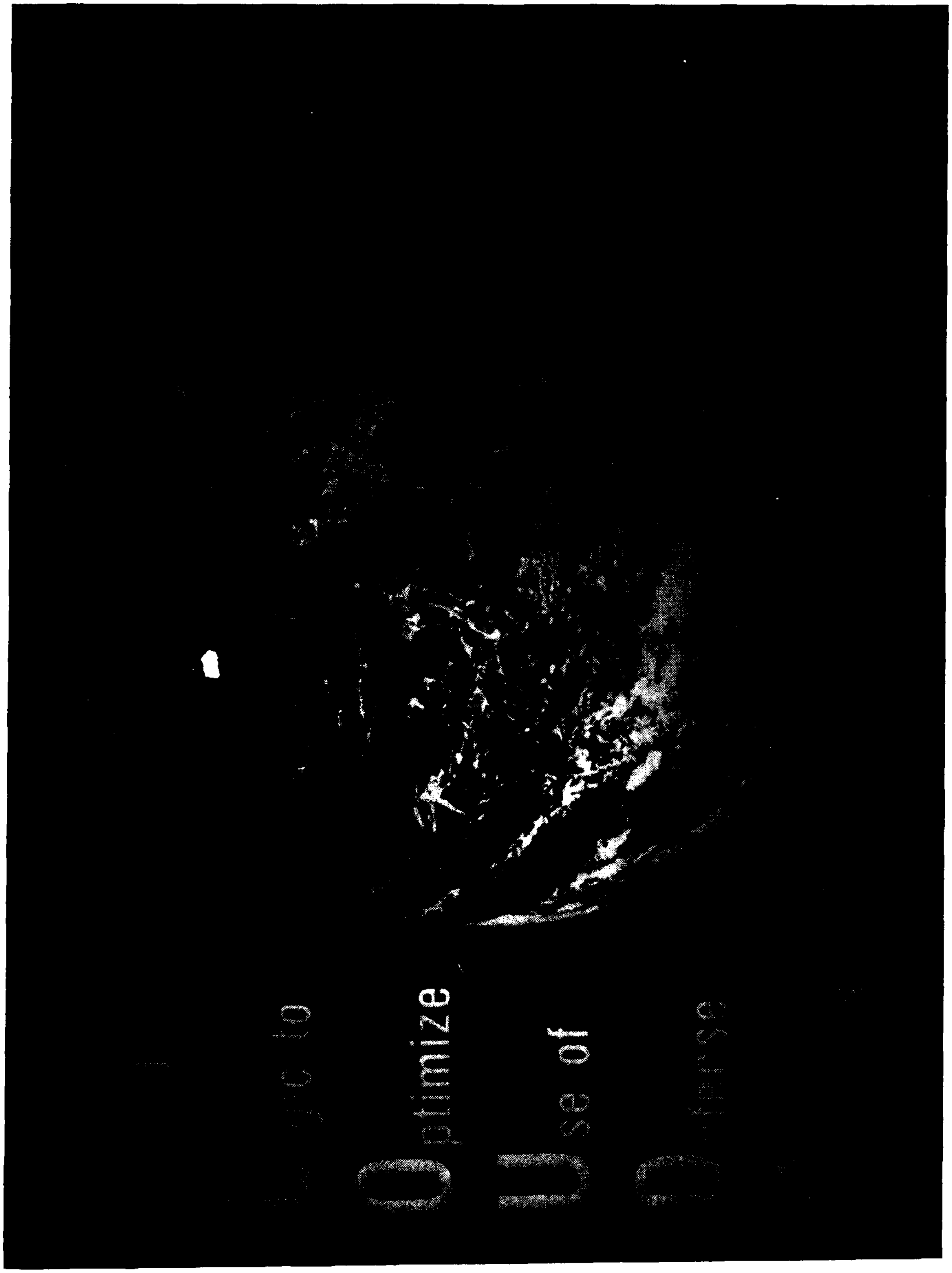
A topic that most Workshop attendees agreed would be an asset to the user community was the establishment of a Clearing House which would be a tri-service focal point for cloud data bases and methodologies. This group could provide background information for "newcomers" and guide users to the data bases and techniques most applicable to their requirements. This would include such items as caveats, computer formats, etc. The tri-service committee will initiate action on this item during the next year.

PART II

BRIEFING CHARTS AND SUPPLEMENTARY MATERIALS

CLOUDS PROGRAM
A BRIEF PERSONAL HISTORY/PURPOSE

Lt Col Vernon Bliss
Air Force Weapons Laboratory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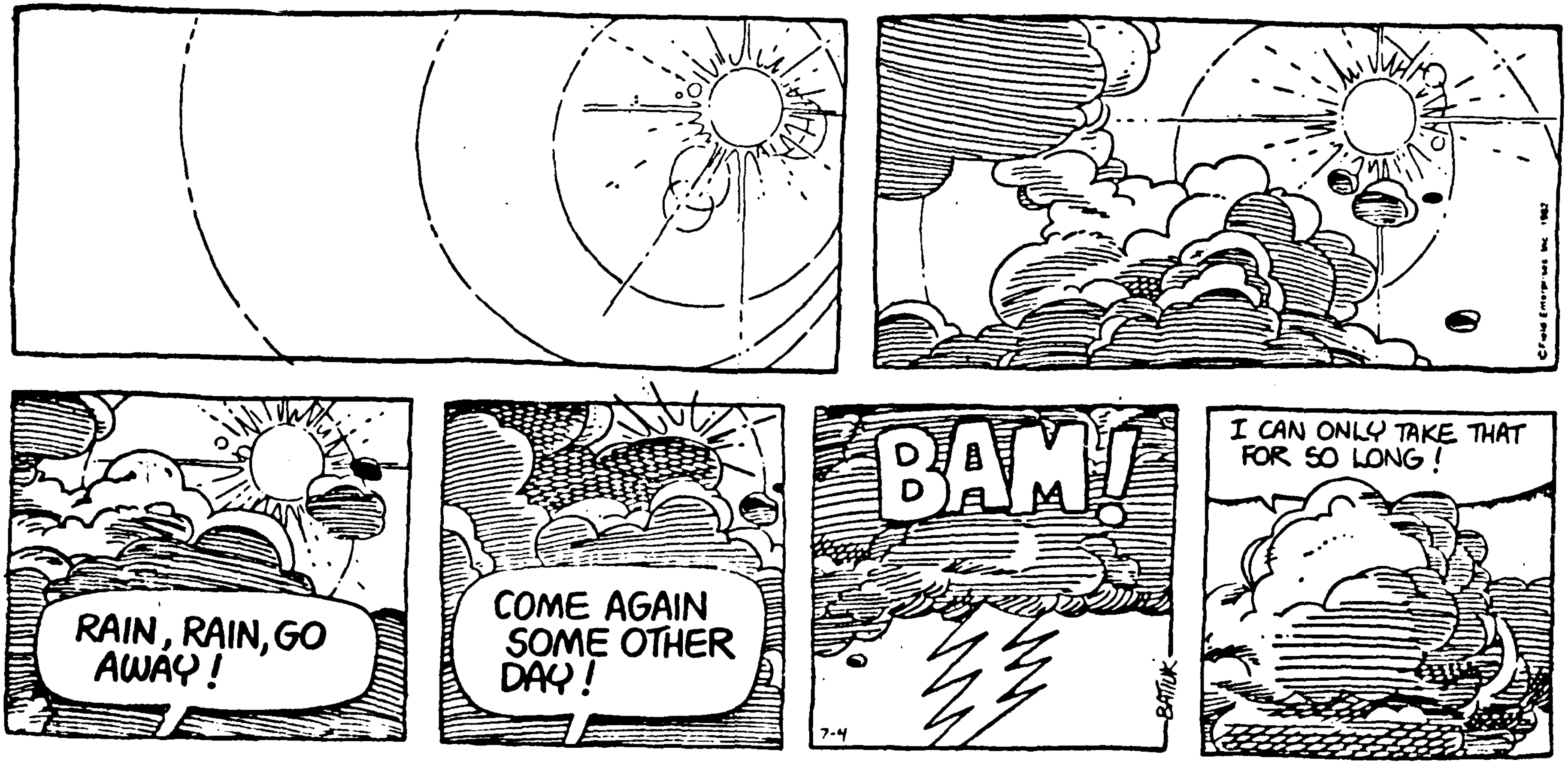
A BRIEF PERSONAL HISTORY/PURPOSE

AFWL/WE

LT COL VERN BLISS

26 JUN 84

IN THE BEGINNING......



WHY A PROGRAM?

1. MANY DOD SYSTEMS AFFECTED BY CLOUDS

   NO SYTEMATIC, CONTINUING ATTACK ON THE PROBLEM

   - BITS & PIECES BUT MANY HOLES

3. NO STANDARD METHODOLOGY AVAILABLE

4. NO SINGLE MANAGER TO COORDINATE EFFORTS

CLOUDS - 1982

- THE ORIGINAL PERPETRATORS

  LCDR STAN GRIGSBY (NAVY HEL)

  LTCOL ED TOMLINSON (FORMERLY AFWAL/WE)

  DR ERNIE BAUER (IDA)

  COL PAUL TRY (FORMERLY OUSDRE-E&LS)

- THE ACRONYMN - 1983

WE OWE IT ALL TO TRY ("YOU CAN'T SELL A PROGRAM WITHOUT A NAME."
AND TO TOMLINSON (3 DAYS WITH A THESAURUS)

CO-CONSPIRATORS

AFGL/LY

GRANTHAM

MCCLATCHEY

DOD SUPPORT

DARPA ?

OUSDRE - DEP. EDITH MARTIN

DATES

22-23 OCT 81:	WORKSHOP ON CLOUD EFFECTS ON SPACE SYSTEMS (DARPA)
29-30 JUN 82:	WORKSHOP ON CLOUD EFFECTS ON SPACE SYSTEMS
10 AUG 82:	MEMO FROM EDITH MARTIN (DEP OUSDRE) TO AFSC/DL --- TRI-SERVICE INITIATIVE WITH AFGL LEAD
9-10 NOV 82:	TRI-SERVICE PLANNING GROUP FOR CLOUD MODELING (AFGL MEETING)
1 JUN 83:	BRIEFING TO DARPA/DEO ---THE SEARCH FOR MONEY --- CLOUDS NAME APPEARED
28-30 JUN 83:	TRI-SERVICE CLOUD MODELING WORKSHOP --- EXPANSION OF PROGRAM INTO SOFTWARE/DATABASE DELIVERABLES (LOWTRAN / FASCODE ANALOGY)
8 JUL 83:	AFGL/CC APPROVED AFGL LEAD IN CLOUDS
15 JUL 83:	AFSTC/CC APPROVED AFGL INVOLVEMENT IN CLOUDS
26 JUL 83:	AFGL/CC ---REFINE USER REQUIREMENTS
29 JUL 83:	REBRIEF TO DARPA/DEO ---RECOGNITION OF NEED BUT NO FINANCIAL COMMITTMENT
23-24 FEB 84:	PLANNING MEETING AT IDA --- "PERSISTENCE PAYS OFF"
26-28 JUN 84:	SECOND TRI-SERVICE CLOUD MODELING WORKSHOP

RECAPITULATE PURPOSE

1. DEVELOP DOD STANDARD DATA BASE & SOFTWARE
   - MAINTAINED & IMPROVED ON A CONTINUING BASIS BY AFGL (LOWTRAN/FASCODE ANALOGY)
   - START SIMPLE & GROW COMPLEX
   - KEEP EFFORT TRI-SERVICE
2. REFINE USER REQUIREMENTS IN THE CLOUD ARENA
3. MAINTAIN DOD & CONTRACTOR USER/TECHNICAL COMMUNITY AWARENESS - ANNUAL MEETING

STATUS

LIMPING ALONG

- WIDE RECOGNITION OF CLOUD ISSUES BUT LITTLE FINANCIAL SUPPORT

- SINCE IT'S VERY MUCH A GENERIC PROBLEM,

  "LET THE OTHER GUY FUND IT!"

FUTURE

?

BE PERSISTENT!

CLOUDS PROGRAM

SUPPLEMENTAL MATERIAL

LT COL VERNON BLISS, AFWL

CLOUDS & DOD

Beam Weapons

Clouds stop beam

Radiation must remain on target for a finite time

Detectors

Can't see through clouds

Need to view target finite time to detect & identify

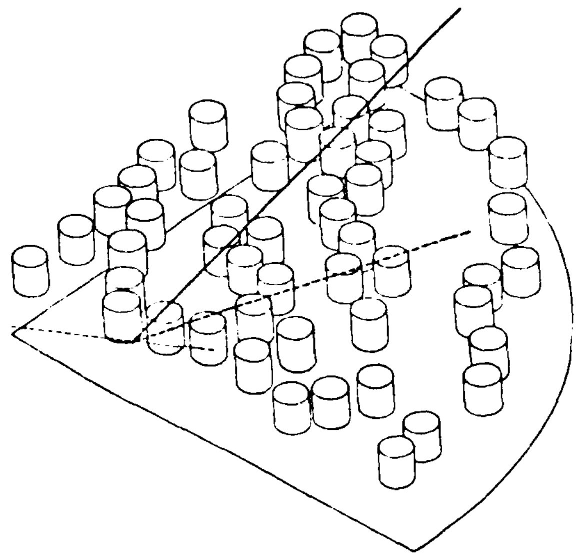
METHODOLOGIES

Stochastic(statistical)

determines clear or cloudy as function of probability

Deterministic

runs line-of-sight intersections against actual clouds



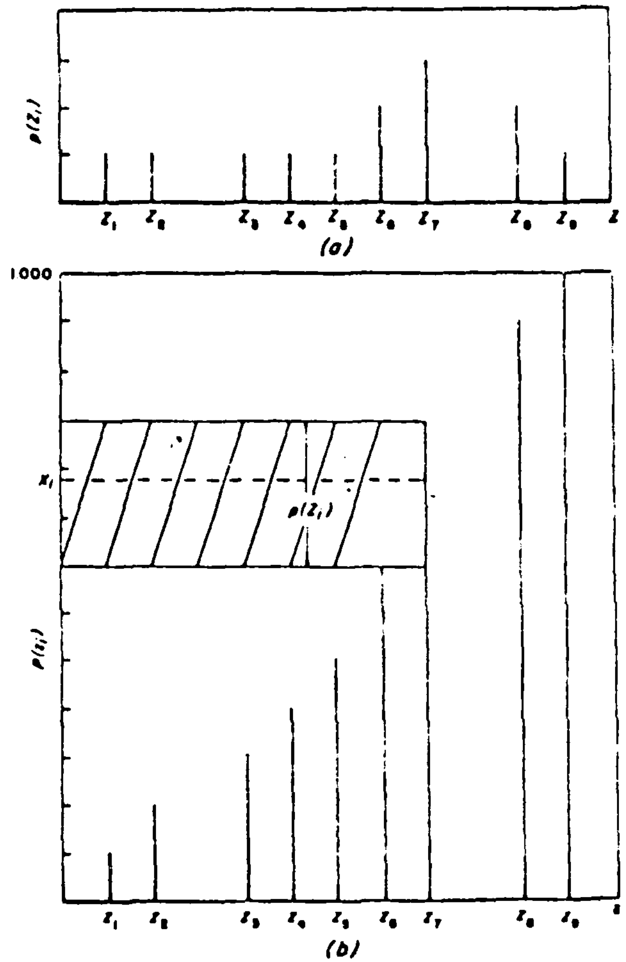


Figure 21.20
(a) Frequency function for arbitrary discrete distribution of Z. (b) Cumulative distribution function corresponding to (a). It illustrates choice of a random number drawn from the arbitrary distribution of Z.

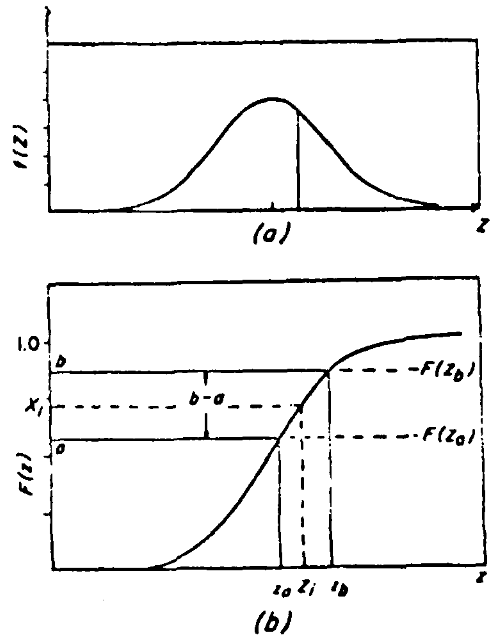
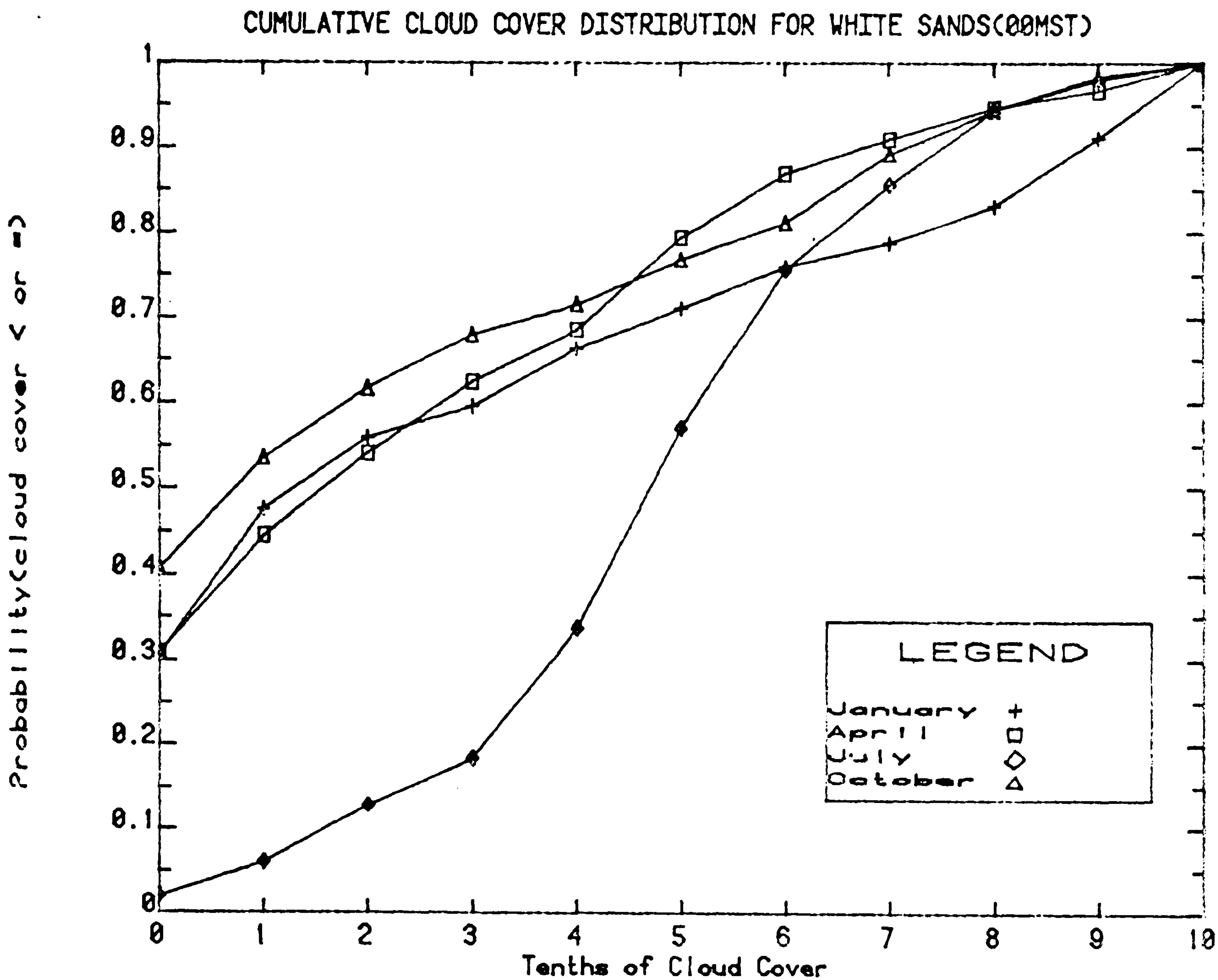


Figure 21.21
(a) Probability density function for arbitrary continuous distribution in Z. (b) Cumulative distribution function corresponding to the p.d.f. of (a). Illustrates choice of a random number drawn from the arbitrary (continuous) distribution of Z.


CUMULATIVE CLOUD COVER DISTRIBUTION FOR WHITE SANDS(00MST)
Probability(cloud cover < or =)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Tenths of Cloud Cover
0
1
2
3
4
5
6
7
8
9
10
LEGEND
January
April
July
October

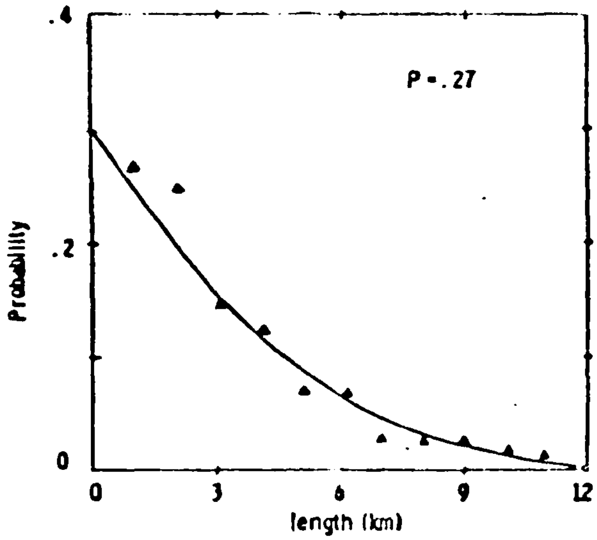


Figure 4. Exponential clear runs

μ = mean length

P = probability CFLOS

Q = probability no CFLOS

P + Q = 1

MEAN CLEAR LENGTH

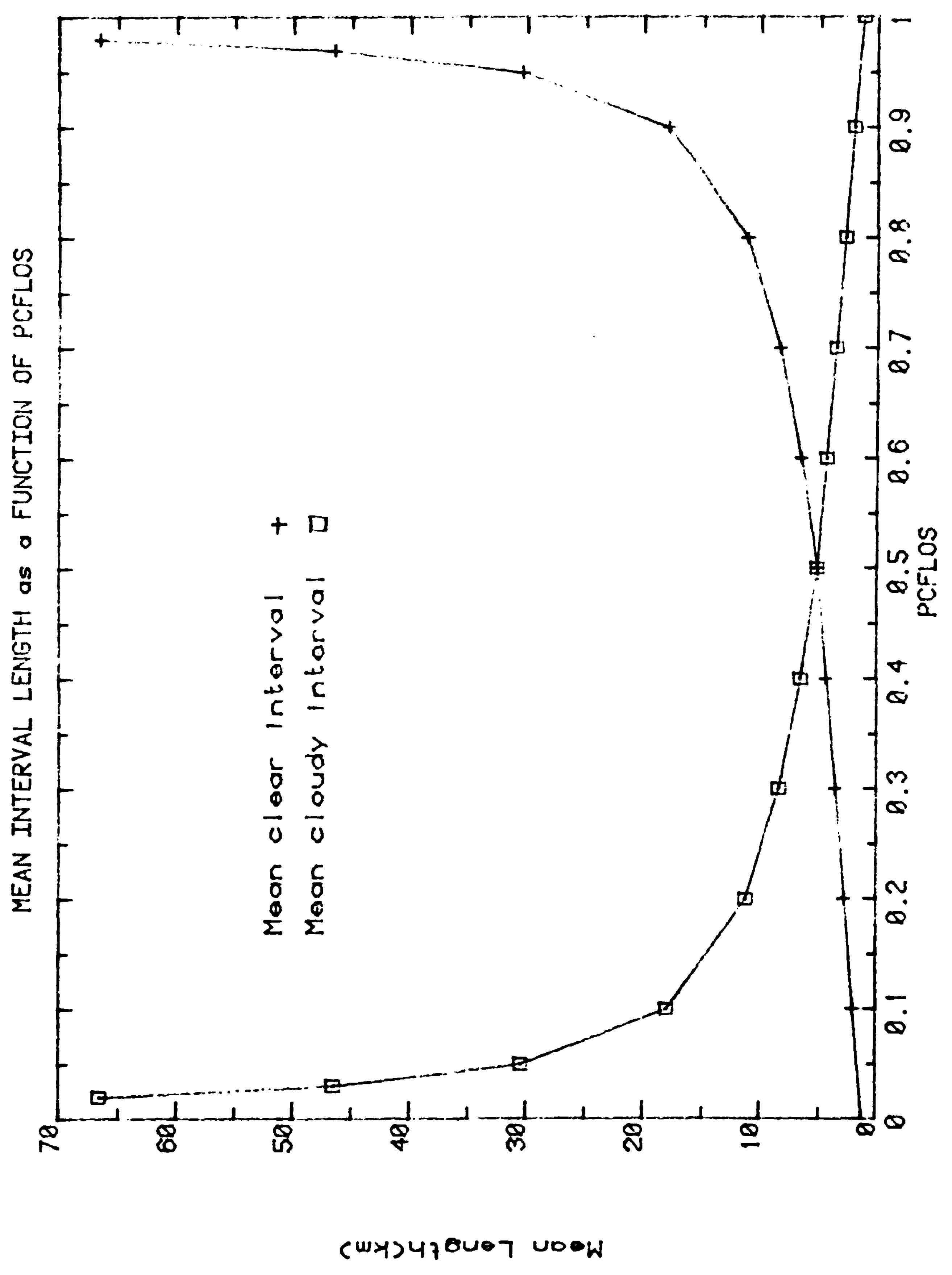
$\mu(P) = 8P + 1.2 \qquad 0 \leq P \leq .5$

$\mu(P) = (P/Q)(8Q + 1.2) \qquad .5 < P \leq 1.0$

MEAN CLOUDY LENGTH

$\mu(Q) = 8Q + 1.2 \qquad 0 \leq Q \leq .5$

$\mu(Q) = (Q/P)(8P + 1.2) \qquad .5 < Q \leq 1.0$


MEAN INTERVAL LENGTH as a FUNCTION OF PCFLOS
Mean clear Interval +
Mean cloudy Interval □
PCFLOS
Mean Length(km)
0
10
20
30
40
50
60
70
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

EXPONENTIAL DISTRIBUTION

DENSITY FUNCTION

$$P(L;\mu) = \frac{1}{\mu}\ \mathrm{EXP}\left(-L/\mu\right)$$

CUMULATIVE DISTRIBUTION

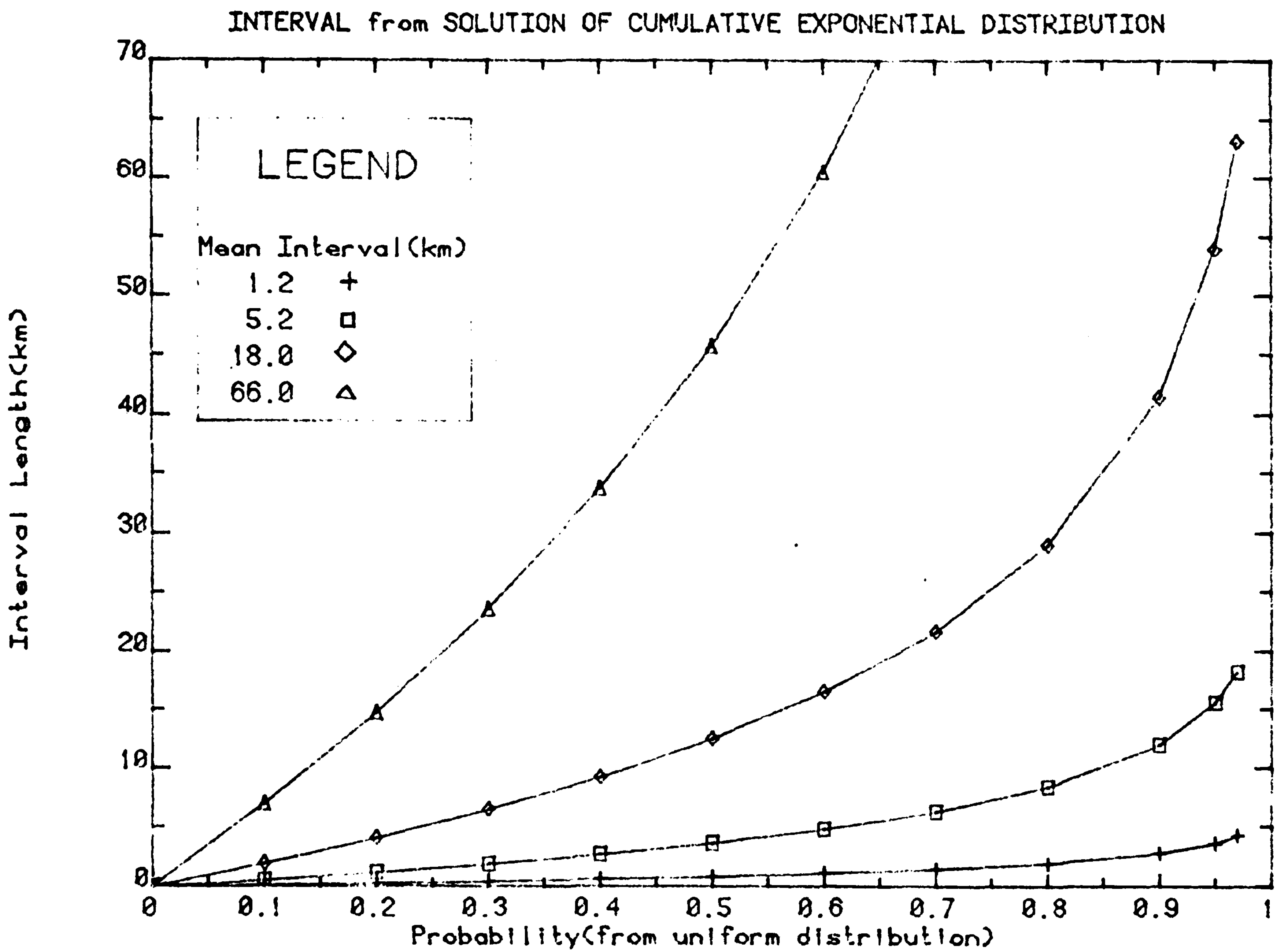
$$P(0 \leq L \leq L^*) = 1 - \mathrm{EXP}\left(-L^*/\mu\right)$$

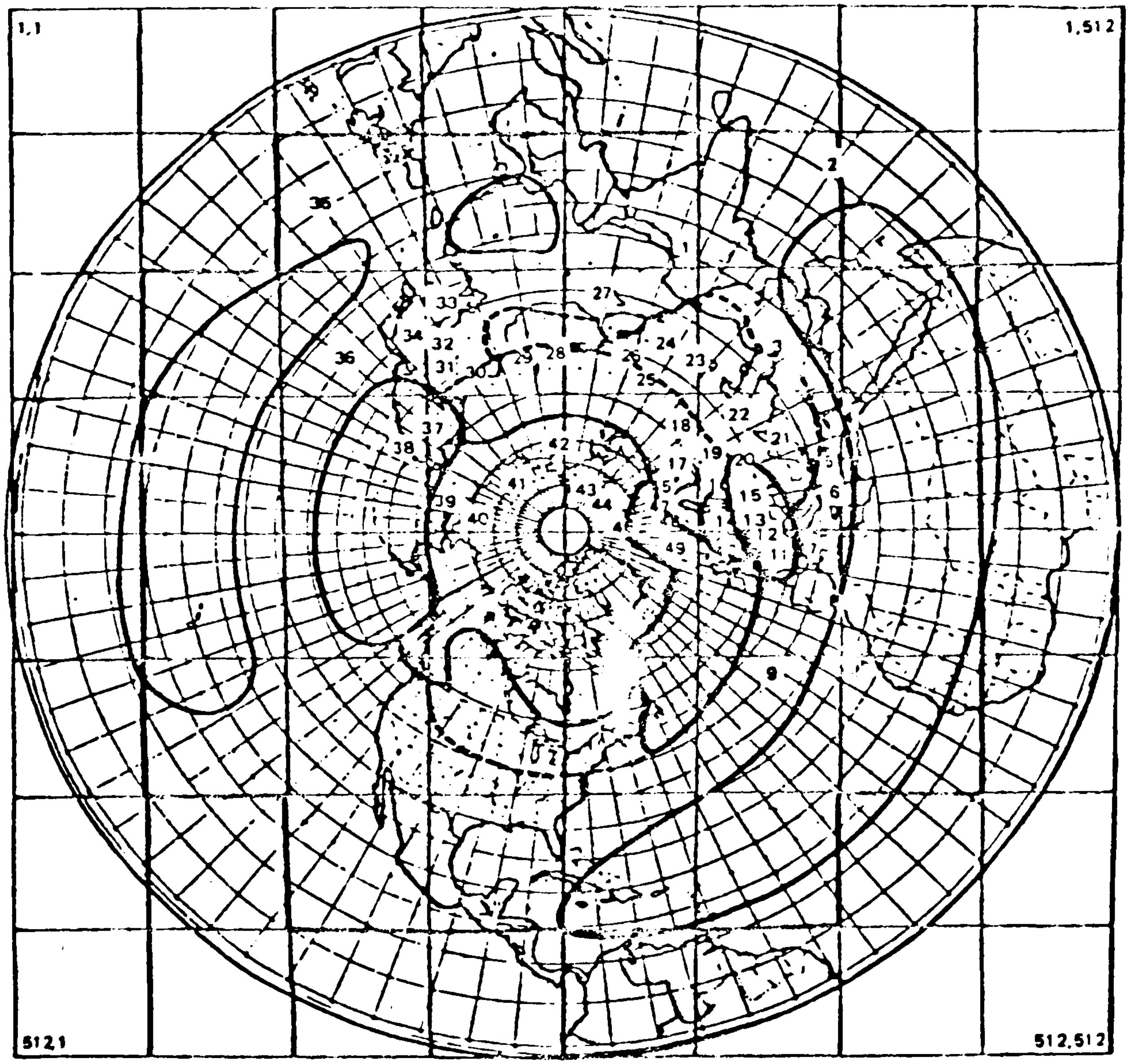
DRAW FROM EXPONENTIAL DISTRIBUTION FOR L

$$L = -\mu\,\mathrm{LN}\,(1 - P)$$

WHERE P IS DRAWN FROM A UNIFORM DISTRIBUTION BETWEEN

Ø AND 1


INTERVAL from SOLUTION OF CUMULATIVE EXPONENTIAL DISTRIBUTION
LEGEND
Mean Interval(km)
1.2 +
5.2 □
18.0 ◇
66.0 △
Interval Length(km)
0
10
20
30
40
50
60
70
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Probability(from uniform distribution)



UNCLASSIFIED

FIGURE 4 · 3DNEPH GRID, REGIONS, AND DATA-SET LOCATIONS (U)

(U) LOCATIONS OF DATA SET (U)

	Page	Lat/Long		3DNEPH Coordinates
Southern Asia	26			
1. New Delhi		29.2 N	78.0 E	(117, 315)
2. Arabian Sea		8.0 N	65.4 E	(73, 385)
3. Teheran		36.2 N	52.2 E	(169, 355)
Mediterranean	44			
4. Suez		30.5 N	31.4 E	(203, 395)
5. Sea of Crete		37.1 N	26.2 E	(221, 381)
6. Ionian Sea		38.5 N	18.1 E	(239, 381)
7. Western Mediterranean		41.0 N	5.8 E	(265, 375)
8. Gibraltar		36.5 N	5.5 W	(291, 383)
Europe	74			
9. Azores		40.6 N	26.7 W	(327, 353)
10. North Sea		57.3 N	2.0 E	(267, 333)
11. Paris		49.2 N	2.5 E	(269, 353)
12. Frankfurt		50.3 N	8.5 E	(259, 351)
13. Berlin		52.7 N	13.6 E	(251, 345)
14. Copenhagen		55.9 N	12.6 E	(253, 337)
15. Warsaw		53.0 N	20.4 E	(241, 343)

Continued...

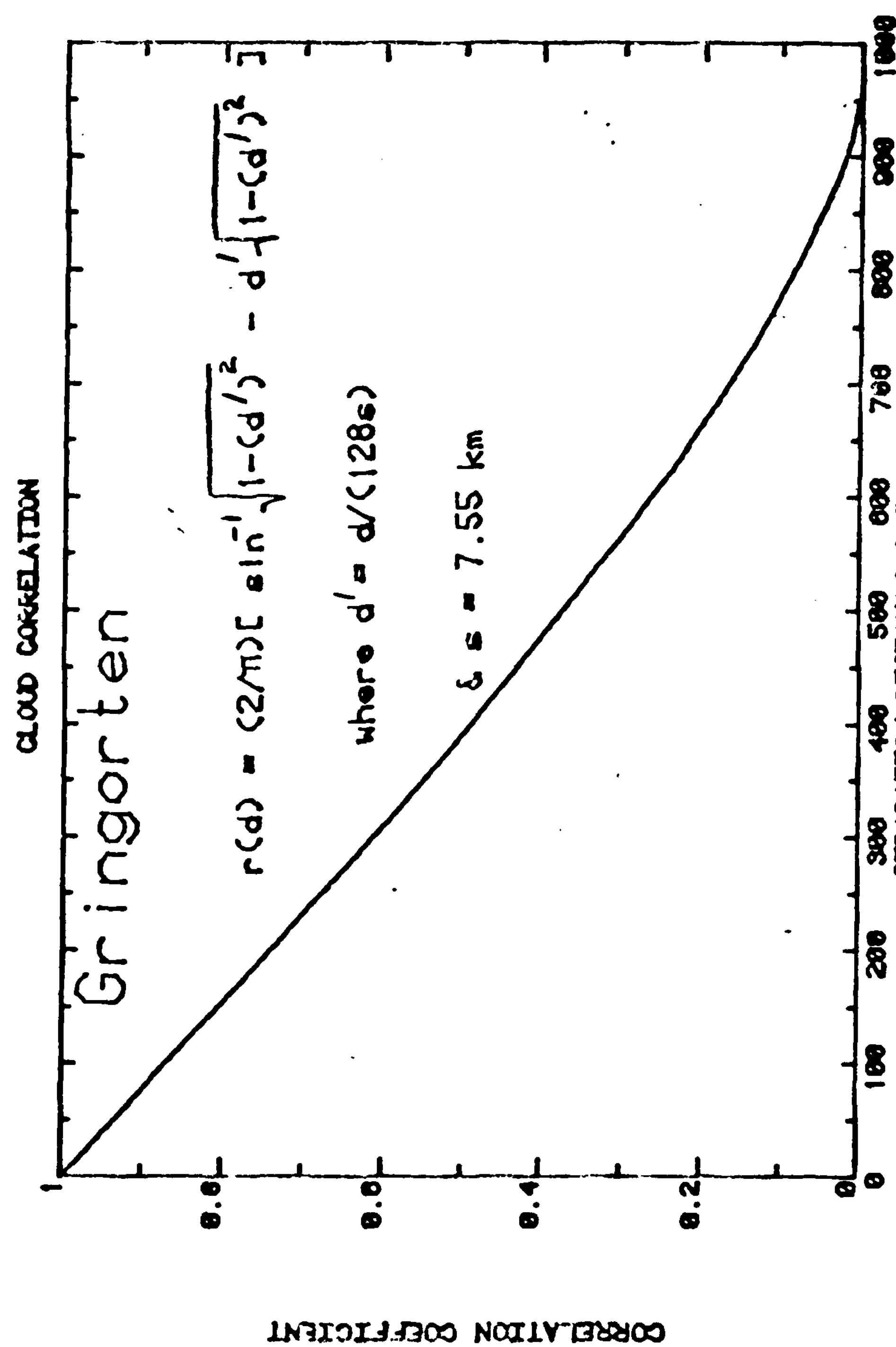
CLOUD CORRELATION

Malick & Allen--------Bliss

$$c_k = (1-r)c'_k + rc_{k-1}$$

for equal intervals

$$c_k = c'_1 r^{k-1} + \sum_{j=0}^{k-2} (1-r) r^j s'_{k-j}$$


CLOUD CORRELATION
Gringorten
r(d) = (2/π)[sin⁻¹√(1-(d')²) - d'√(1-(d')²)]
where d' = d/(128s)
s = 7.55 km
SEPARATION DISTANCE (KILOMETERS)
CORRELATION COEFFICIENT
0
100
200
300
400
500
600
700
800
900
1000
0.2
0.4
0.6
0.8
1

SRI MODEL LIMITATIONS

Everything analytically modeled

many simplifying assumptions

Limited track & interval results

No spatial correlation

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OVERVIEW OF METHODOLOGIES AND CAVEATS FOR MODELING CFLOS, CFFOV AND CFI

Donald D. Grantham
Air Force Geophysics Laboratory

OVERVIEW OF METHODOLOGIES AND CAVEATS FOR MODELING CFLOS, CFFOV AND CFI

DONALD D. GRANTHAM
AFGL

LUND-SHANKLIN CFLOS MODEL

- BASED ON > 3 YRS OF DAYLIGHT WHOLE SKY PHOTOS
  - 3-HOURLY, 0900, 1200, 1500 LST
- CORRELATED TO SIMULTANEOUS NWS SKY COVER OBSERVATIONS
- DEVELOPED "UNIVERSAL" MODEL
- DEVELOPED CLOUD-TYPE MODEL
  - CIRRIFORM, MIDDLE (ALTO), CUMULIFORM, STRATIFORM
- MATRIX MODELS USE AS INPUT CLIMATIC SKY COVER, K

$$_{\alpha}P_1 = {_{\alpha}C_S}\, K_1$$

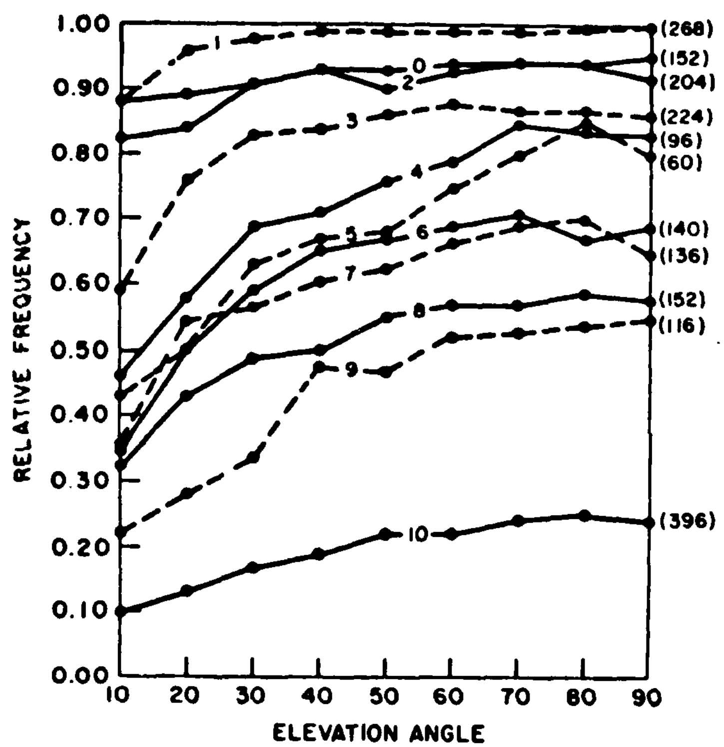


Fig. 3. Same as Fig. 2 except that the data sample was limited to those hours with only cirriform clouds (cirrocumulus, cirrostratus, or cirrus).

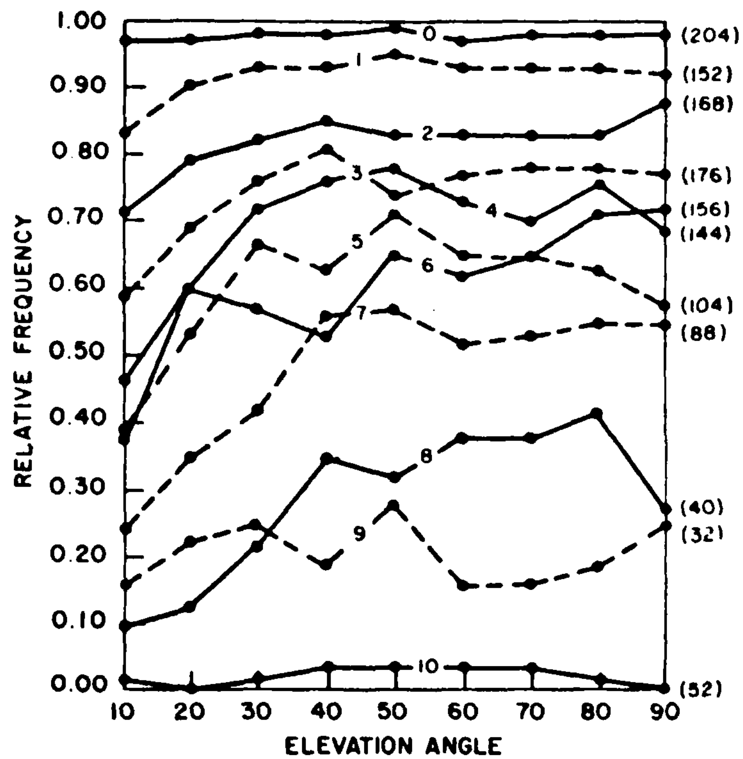


Fig. 5. Same as Fig. 3 except for only cumuliform clouds (cumulonimbus, cumulonimbus mammatus, cumulus, or fractocumulus).

LUND-SHANKLIN CFLOS MODEL

ATTRIBUTES

- EASE OF APPLICATION
- CLIMATIC SKY COVER INPUT AVAILABLE WORLDWIDE
- GENERALLY ACCEPTED WITHIN METEORLOGICAL COMMUNITY

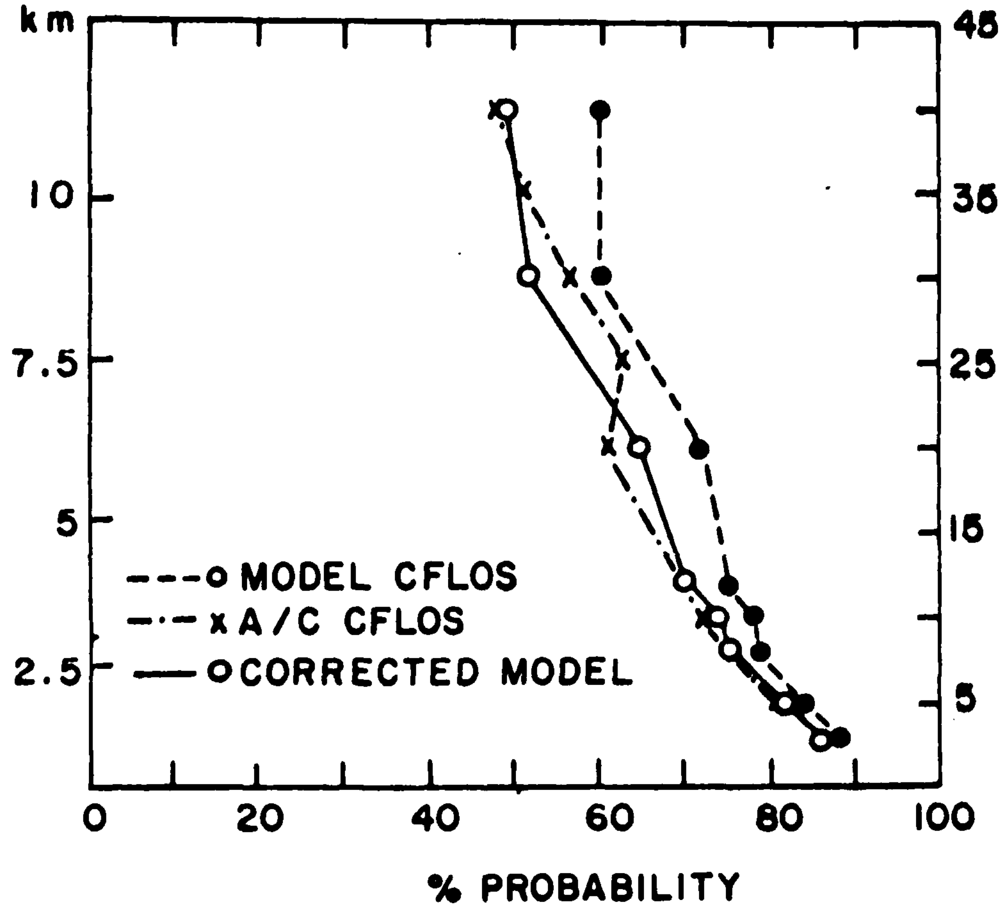
WEAKNESSES

- "UNIVERSALITY" NEEDS TO BE VALIDATED
  - *TROPICAL, POLAR, COASTAL AND DESERT LOCATION*
- DID NOT SAMPLE NIGHT-TIME CLOUD SCENES
- CLOUD TYPE MODEL NEEDS LARGER SAMPLES
- MAY HAVE SLIGHT BIAS TOWARD HIGH PCFLOS VALUES
  - WHOLE-SKY PHOTOS MAY NOT DETECT THIN CLOUDS SEEN BY GROUND OBSERVERS

<u>MODIFICATION OF LUND-SHANKLIN CFLOS MODEL</u>

- BASED ON COMPARISON WITH BERTONI'S AIRCRAFT CFLOS DATA AT 6 US LOCATIONS, AFGL-TR-80-0046

$$P^* = (0.99 - 0.0045A)P \; ; \; 0 < A < 45 \text{ KFT}$$



SIX-STATION AVERAGE PROBABILITIES OF CLFOS DETERMINED FROM AIRCRAFT OBSERVATIONS AT A DEPRESSION ANGLE OF 60^{0}

JOINT PROBABILITIES OF CFLOS*

- REQUIRES CLIMATIC RECORD OF SKY COVER OBSERVATIONS TAKEN SIMULTANEOUSLY FROM ALL SITES

- TWO- AND THREE-WAY JOINT PCFLOS GIVEN FOR GRAND FORKS, FARGO AND MINOT, ND

*LUND, AFCRL TR-73-0178

PERSISTENCE AND RECURRENCE PROBABILITIES OF CFLOS*

- USED COLUMBIA, MO WHOLE SKY PHOTOS
  - 585 HRS OF 5-MIN DATA
  - 885 DAYS OF HOURLY DATA, 0900-1500 LST
- DERIVED CLOUD-FREE AND CLOUDY PERSISTENCE AND RECURRENCE FREQUENCIES AS FUNCTION OF CLOUD COVER
- DEVELOPED MATRIX MODEL TO ESTIMATE PERSISTENCE AND RECURRENCE PROBABILITIES FOR LOCATIONS HAVING SKY COVER CLIMATOLOGIES

STRENGTHS/WEAKNESSES

SIMILAR TO THOSE FOR LUND/SHANKLIN CFLOS MODEL

*LUND, 1973: JAM VOL 12, No. 7

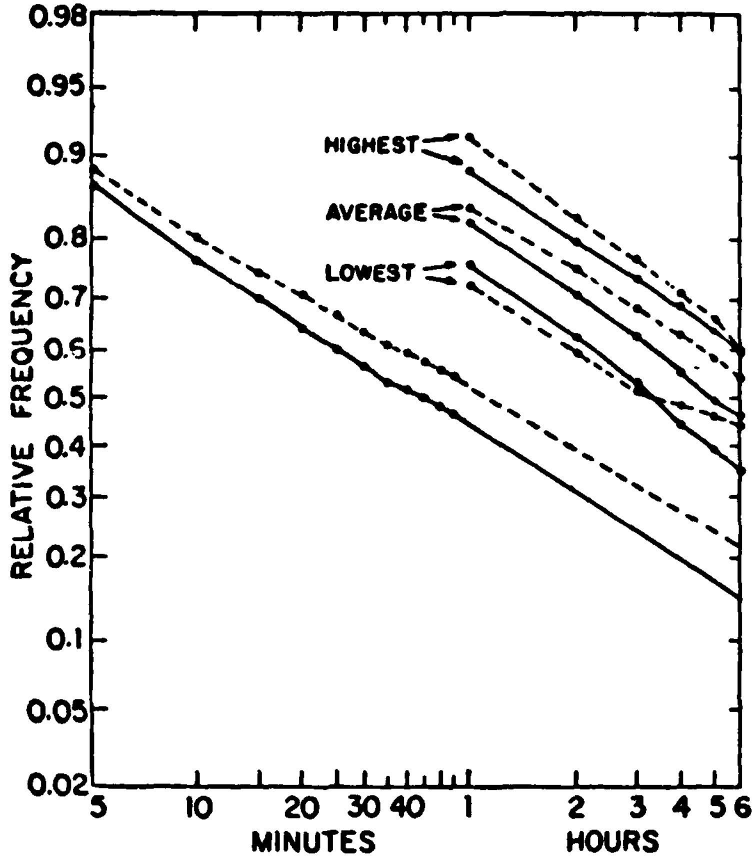


FIG. 2. Cloud-free (solid lines) and cloudy (dashed lines) ersistence relative frequencies obtained from whole-sky photo-raphs taken at Columbia, Mo. (see text).

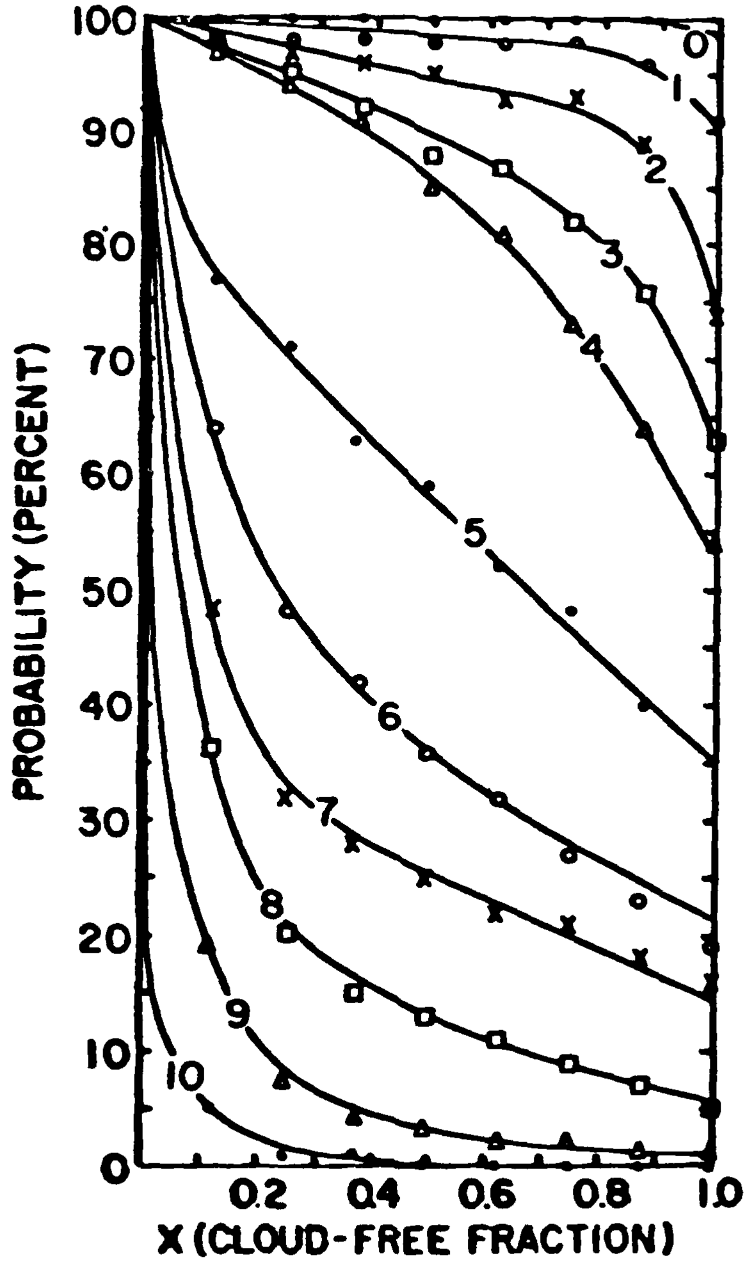
CLOUD FREE FIELDS OF VIEW MODEL*

- REANALYZED 3 YR WHOLE SKY PHOTOS FROM COLUMBIA, MO
- USED 185 SECTOR PHOTO OVERLAY
- DETERMINED CLOUD COVER (EIGHTS) FOR EACH SECTOR
- DEVELOPED MATRIX MODEL - USES CLIMATIC SKY COVER AS INPUT

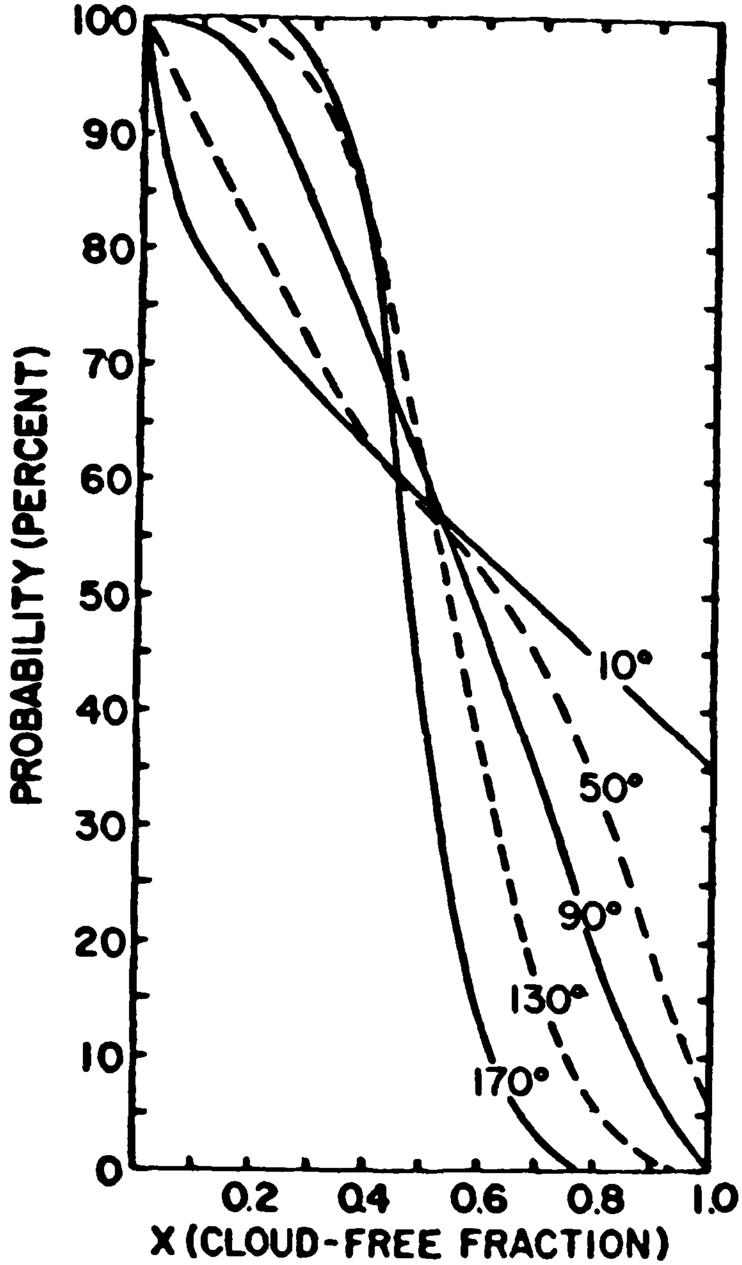
STRENGTHS/WEAKNESSES

SIMILAR TO THOSE FOR LUND/SHANKLIN MODEL

*LUND, ET AL., JAM, VOL 19, 1980



PROBABILITY THAT A 10°, 50°, 90°, 130° AND 170° FOV AT ZENITH WILL HAVE A CLOUD-FREE FRACTION WHEN THE OBSERVER REPORTS 5/10 SKY COVER



PROBABILITY THAT A 10° FOV AT ZENITH WILL HAVE A CLOUD-FREE FRACTION X

BOEHM SAWTOOTH WAVE SIMULATION MODEL

- ALGORITHMS DEVELOPED FOR COMPUTING PROBABILITIES OF CLOUD-COVER IN AN AREA OR ALONG A LINE-HORIZONTAL
- VERTICAL CLOUD-COVER SIMULATION MODELING WILL BE DISCUSSED BY I. GRINGORTEN

STRENGTHS

- ANALYTIC SIMULATION
- INCORPORATES SEVERAL SIMULATION EFFORTS
  - ALLOWS DEPICTION OF TIME CHANGES FOR AREAL AND LINEAL COVERAGE
  - SIMULTANEOUS HORIZONTAL AND VERTICAL STRUCTURE
  - FRACTAL DEPICTION
- SAWTOOTH REQUIRES MUCH LESS COMPUTER TIME THAN GRINGORTEN'S MODEL B

WEAKNESSES

- HORIZONTAL MODELS NEED VALIDATION
- VERTICAL MODEL NEEDS FURTHER DEVELOPMENT
- NEEDS BETTER VERTICAL CORRELATION OF CLOUD STRUCTURE

SRI MODELS FOR CFLOS AND CFI*

- DEVELOPED ANALYTIC CFLOS MODEL

$$PCFLOS = P_N [1 + B/\tan \alpha]$$

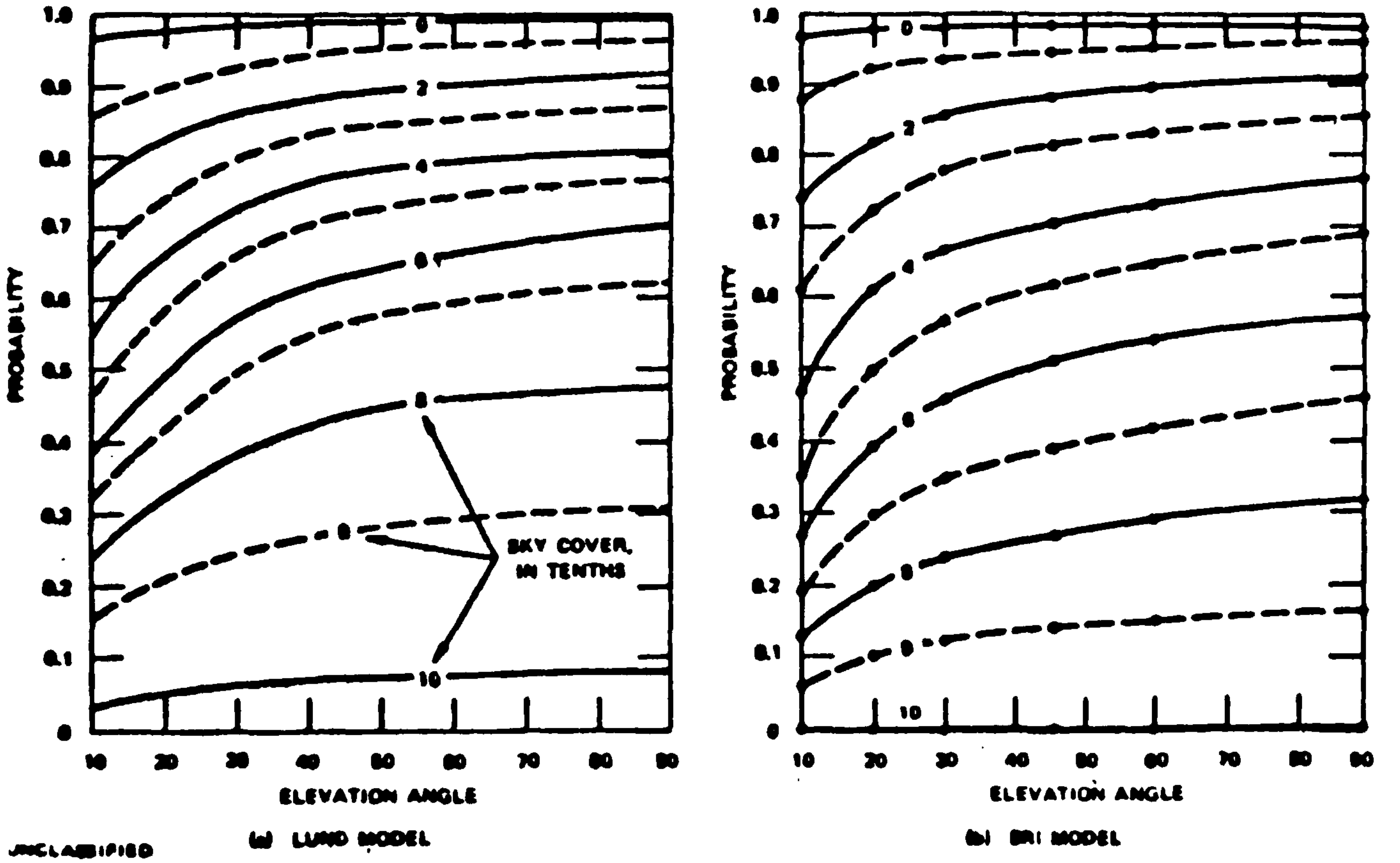
STRENGTHS

- ANALYTIC SOLUTION
- PCFLOS INTEGRATED OVER WHOLE SKY = 1 - SKY COVER THUS MAY OVERCOME THIN CLOUD BIAS IN COLUMBIA WHOLE SKY PHOTOS
- ESTIMATES RELATIONSHIP OF SKY COVER TO EARTH COVER

WEAKNESSES

- ASSUMES AVERAGE CLOUD HEIGHT TO WIDTH RATIO, B
- NOT MODELED BY CLOUD TYPE
- NEEDS VALIDATION

*MALICK, ET AL, SPIE VOL 195, 1979



3. Probabilities of CFLOS as a function of elevation angle and observed total sky cover, in tenths.

SRI MODEL FOR CFI

DEVELOPED METHODOLOGY TO CALCULATE PCFI OF VARIOUS LENGTHS WITHIN A STRAIGHT LINE PATH OF ANY LENGTH.

STRENGTHS

- CAN BE APPLIED TO ANY LOCATION WITH CLOUD COVER CLIMATOLOGY
- HAS BEEN USED WITH 3-DNEPH DATA TO PROVIDE CFI IN VARIOUS ALTITUDE LAYERS

WEAKNESSES

- DEVELOPED FROM ONLY 1 MONTH (JUN 78) OF NOAA DIGITAL SATELLITE DATA
- MAY BE LESS RELIABLE FOR LONG PATHS (> 300 KM)
- NEEDS VALIDATION

CALIBRATED ANALYTICAL MODELING OF CLOUD-FREE INTERVALS

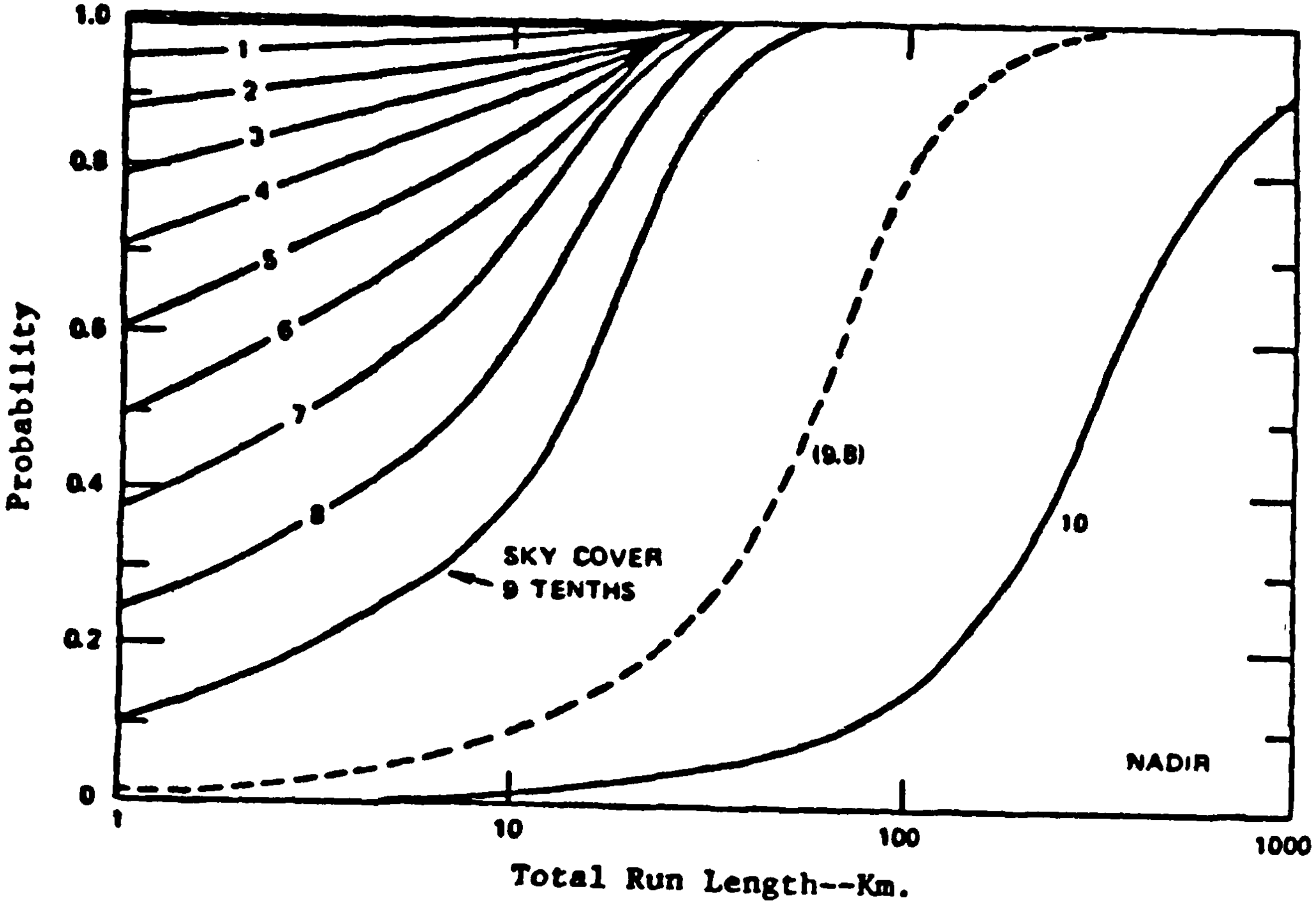


Figure 6. Probability of clear interval greater than 1 Km. with specified sky-cover conditions.

AFWL CLOUDS [1] (SCENE GENERATOR) AND CLOUD IMPACT MODEL [2] (CIM)

- CLOUDS DEVELOPS 3-D CLOUD SCENES WITH CYLINDRICAL AND TRUNCATED ELLIPSOIDS (INCLUDING SPHERES)

  - CLOUD VARIABLES: SHAPE, BASE HEIGHT, THICKNESS RADIUS (MAJOR, MINOR AXES) SKY COVER AS FUNCTION OF HEIGHT AND CLOUD TYPE

- TRAJECTORY ANALYSIS PROGRAM ALLOWS USERS TO OVERLAY THE KINEMATICS OF AN ENGAGEMENT ON CLOUD FIELD

- CIM COMBINES CLOUDS PROGRAM WITH EO SYSTEMS CHARACTERISTICS, TARGET SIGNATURES AND ENGAGEMENT DYNAMICS TO PRODUCE LINE OF SIGHT AND CLOUD CLUTTER EVALUATIONS

1. SEAGER, M., 1980: AFWL TR 79-164
2. NELSON, R.J. AND LEWIS, M., 1979: AFWL TR 79-108

AFWL CLOUDS [1](SCENE GENERATOR) AND CLOUD IMPACT MODEL [2](CIM) - CONTINUED

STRENGTHS

- QUANTIFIES CONCURRENT CLOUD INDUCED DEGRADATION TO OFFENSIVE AND DEFENSIVE EO SYSTEMS
- USER CAN STRUCTURE OUTPUT IN TERMS OF CONDITIONAL EFFECTIVENESS PROBABILITIES

WEAKNESSES

- GEOMETRICALLY SHAPED CLOUDS IN CLOUDS PROGRAM
- "CLOUDS" IS NOT COMPUTER EFFICIENT

CONDITIONAL PROBABILITIES MAY HAVE NO RELATIONSHIP TO MULTI-LAYERED CLOUD

CLOUD DATA BASES: OVERVIEW AND CAVEATS

J. Bunting
Air Force Geophysics Laboratory

CLOUD DATA BASES: OVERVIEW AND CAVEATS

BY: J. BUNTING, AFGL

TO: TRI-SERVICE CLOUD MODELING WORKSHOP

26 JUNE 1984

SOURCES OF CLOUD DATA

SURFACE: WEATHER OBSERVERS,CAMERAS, RADAR, LIDAR

BALLOONS: HUMIDITY, TEMPERATURE SOUNDING

AIRCRAFT: PARTICLE SAMPLING, OPTICAL MEASUREMENTS

SATELLITES: OPTICAL MEASUREMENTS

CLOUD OBSERVATIONS FROM WEATHER STATIONS

PROS:

LONGEST RECORDS

WORLDWIDE STANDARDS

GOOD CLOUD BASES

INCLUDE PRECIPTATION, VISIBILITY

HUMAN INTERPRETATION

CONS:

HUMAN VARIATION

EMPHASIS ON AVIATION

DATA-SPARCE AND DATA-DENIED AREAS

CLOUD TOPS AND HIGH CLOUDS
UNKNOWN OR POORLY RESOLVED

NIGHT OBSERVATIONS LIMITED

WEATHER STATION SOURCES

ORIGINAL REPORTS: ETAC(DATSAV), NCC

NEPHANALYSIS: RTNEPH

SUMMARIES: FREQUENCY OF OCCURRENCE,
CLOUD AND CFLOS ATLASES

RADIOSONDE OBSERVATIONS

PROS:

HUMIDITIES DEFINE CLOUD LAYERS

TEMPERATURES ESTIMATE ICING POTENTIAL

SUPPORT CLOUD GROWTH MODELS

DEFINE TROPOPAUSE

CONS:

NOT FOR SCATTERED CLOUDS

MAY MISS COLDEST CLOUDS

TOO FEW REPORTS FOR GOOD CLOUD MAPS

AIRCRAFT OBSERVATIONS

PROS:

DIRECT SAMPLING OF CLOUD PARTICLES, ICING, TOPS, BASES

GOOD PLATFORM FOR OPTICAL MEASUREMENTS

CONS:

SMALL VOLUMES OF DIRECT SAMPLING

RELATIVELY FEW OBSERVATIONS

NO STANDARDS FOR OBSERVING OR ARCHIVING

SATELLITE OBSERVATIONS

PROS:

ONLY DATA WITH GLOBAL COVERAGE

GOOD CLOUD TOPS AND CLOUD MOTION

MAY BE ONLY SOURCE DURING HOSTILITIES

CONS:

CAN'T DETECT CLOUD BASES
OR RESOLVE SMALLEST CLOUDS

MAY CONFUSE LOW CLOUDS AND CLEAR AREAS

POOR HEIGHT-ASSIGNMENT FOR THIN CLOUDS

MOST PICTURES NOT CONVERTED TO CLOUD MAPS

SATELLITE CLOUD CLIMATOLOGIES

SADLER ET AL.

MILLER - FEDDES

3DNEPH / RTNEPH

ERBE PRODUCTS

ISCCP

LET THE USER BEWARE OF

SOLID CLOUDS

CLOUD TYPES

HOMOGENOUS CLOUDS

RECTANGULAR CLOUDS

ICE PARTICLES

CLOUD DATA BASE NEEDS

INTERCOMPARISON, STANDARDIZATION, AND VALIDATION

THIN CLOUDS

POLAR CLOUDS

SMALL-SCALE STRUCTURE AND VARIATION WITH TIME

EFFICIENT DATA HANDLING FOR LARGE DATA BASES

DARPA'S INTEREST IN CLOUD DATA

David Zimmerman
Photon Research Associates, Inc.

PRA

DARPA'S INTEREST IN CLOUD DATA

D. ZIMMERMAN

PHOTON RESEARCH ASSOCIATES, INC.
3301 N. TORREY PINES CT., STE. 301
LA JOLLA CA 92037

26 JUNE 1984

B-022-84

PRA

DARPA AVD PROGRAM NEEDS FOR CLOUD DATA

- Objectives of DARPA AVD Program
- AVD Cloud Clutter Data Base
  - -- Requirements
  - -- Issues
- AVD Cloud Scene Simulation
  - -- Requirements
  - -- Issues
- AVD Cloud Scene Application Example
  - -- Simulation Technique
  - -- Geometric Source Data
  - -- Simulated Scenes
  - -- Aircraft Flythrough Tracks
  - -- Flythrough Contrast Sequence
- Summary

PRA

OBJECTIVES OF DARPA AIR VEHICLE DETECTION (AVD) PROGRAM

1. Develop Technologies Pursuant to Fielding Operational Surveillance Systems, e.g.,

   - Optics
   - Detectors
   - Filters
   - Coolers
   - Servo
   - Processors

2. Transfer Technologies to Services for Exploitation.

   - Generation of Target, Background, and Environmental Data Bases
   - Development of Models
   - Performance of System/Subsystem Demonstrations (e.g., HI-CAMP, TEAL RUBY)

PRA

AVD CLOUD CLUTTER DATA BASE

PURPOSE

- Establish Target Spatial Contrast Probabilities and Specific Realizations.
- Establish Technology Requirements of System and Processor to Achieve Desired Levels of Clutter Suppression.

REQUIREMENTS

- Global Statistical Representations of Cloud-Induced Clutter versus Season and Time of Day.
- $\sim 0.1\ \mu F$ Sensitivity
- ~ 20 Meter Resolution
- 2 to 15 μm

PRA

CLOUD CLUTTER ISSUES

- Spatial Texture, Correlated Structures, and Edge Gradients.
  - -- Versus Cloud Type and Altitude
  - -- Varied Viewing Angles to Near Horizon
- Time Dependent Variations in Clutter.
  - -- Time Scales on the Order of Stare Periods or Revisit Times
- Cirrus Effects on Terrain Clutter.
  - -- Versus Thickness and Density
  - -- Effect Changes Versus λ
- Traceability of Clutter to Specific Cloud Types and their Spatial Distributions.

PRA

AVD CLOUD SCENE SIMULATION ISSUES

PROBABILITIES

- Proper Accounting of Cirrus in PCFLOS Data Bases
- Validity of Data Bases at High View Angles (>80 Zenith)
- Near Real Time Cloud Cover Forecasting

MODELS

- Techniques for Generating Deterministic Spatial Representations of Cloud Cover
- Treatment of Irregular Surface Radiative Transfer
- Optical Properties of Clouds
  - -- Versus Type
  - -- Versus λ

PRA

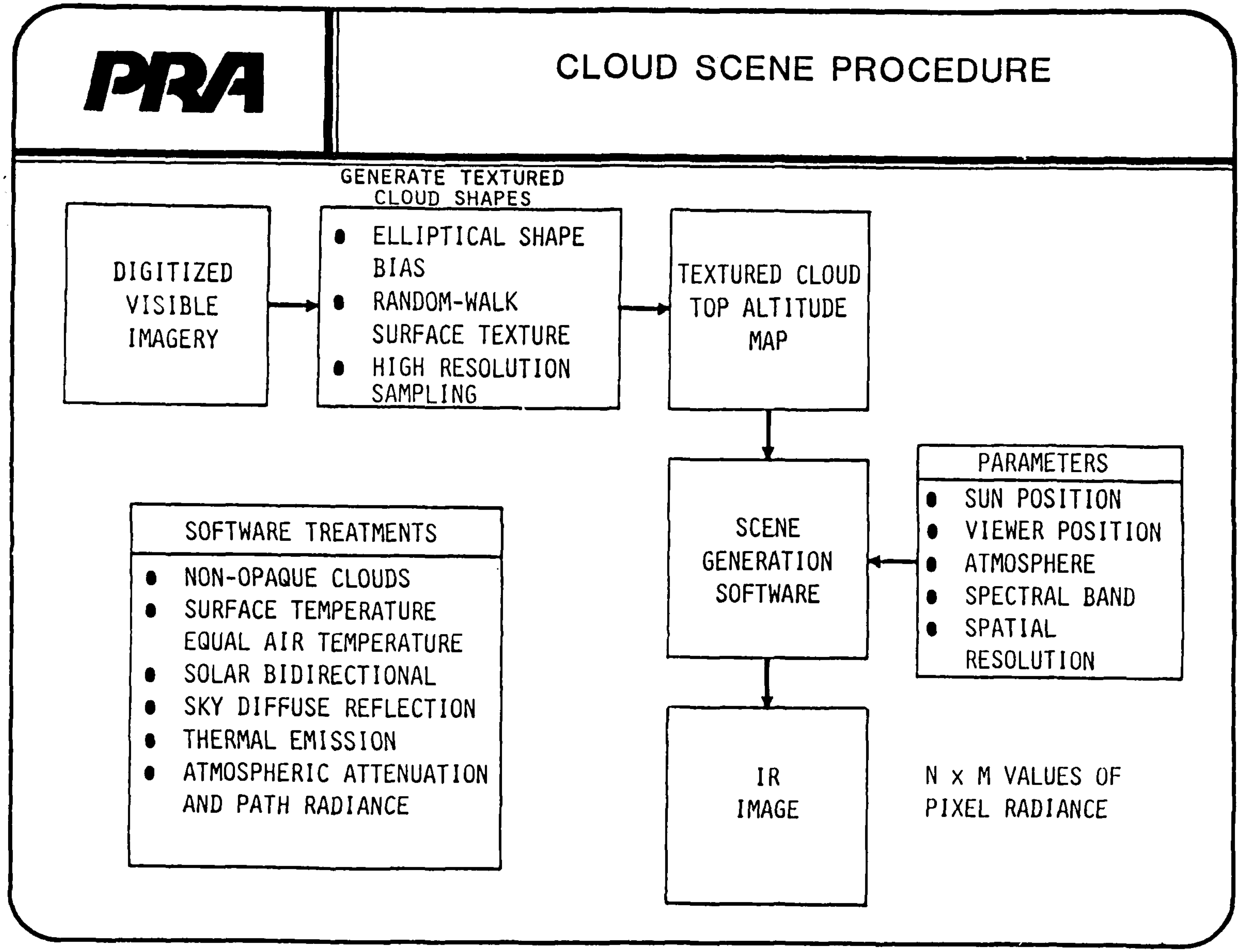
AVD CLOUD SCENE SIMULATION

PURPOSE

- Evaluate System Concepts and Perform First Level System Designs
- Perform End-to-End Simulations of Systems

REQUIREMENTS

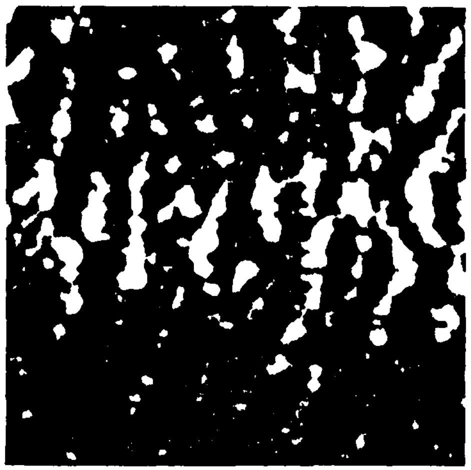
- Probability of Cloud Occurances
  - -- Operational Theaters
  - -- Versus Season and Time of Day
  - -- PCFLOS Versus Track Lengths
  - -- Deterministic Spatial Representations
- Deterministic and Statistical Cloud Scene Models
  - -- Cloud Clutter Statistics (e.g., PSD, PDF of Pixel-to-Pixel Differences)
  - -- Cloud Scene Realizations


PRA
CLOUD SCENE PROCEDURE
DIGITIZED VISIBLE IMAGERY
GENERATE TEXTURED CLOUD SHAPES
• ELLIPTICAL SHAPE BIAS
• RANDOM-WALK SURFACE TEXTURE
• HIGH RESOLUTION SAMPLING
TEXTURED CLOUD TOP ALTITUDE MAP
PARAMETERS
• SUN POSITION
• VIEWER POSITION
• ATMOSPHERE
• SPECTRAL BAND
• SPATIAL RESOLUTION
SCENE GENERATION SOFTWARE
IR IMAGE
N x M VALUES OF PIXEL RADIANCE
SOFTWARE TREATMENTS
• NON-OPAQUE CLOUDS
• SURFACE TEMPERATURE EQUAL AIR TEMPERATURE
• SOLAR BIDIRECTIONAL
• SKY DIFFUSE REFLECTION
• THERMAL EMISSION
• ATMOSPHERIC ATTENUATION AND PATH RADIANCE

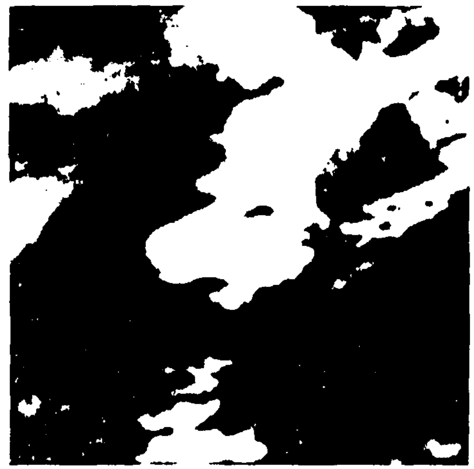
PRA

LOW/HIGH CLOUD VISIBLE IMAGES

LOW ALTITUDE



HIGH ALTITUDE



CLOUD COVER

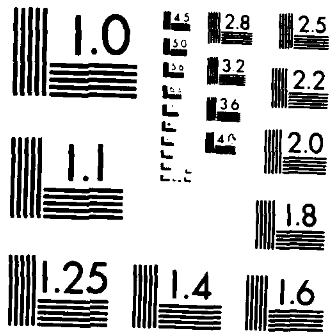
4.5-5.2 μM

8.2-9.2 μM

- CUMULONIMBUS OVER OCEAN
- HEIGHT VARIATION 2-8 Km
- RANDOM-WALK HEIGHT TEXTURE
- FIXED HEIGHT CONDENSATION LEVEL

AD-A152 735 PRESENTATIONS AT THE TRI-SERVICE CLOUD MODELING WORKSHOP (2ND) HELD AT TH..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA E BAUER AUG 84 IDA-M-9-VOL-1 2/7

UNCLASSIFIED IDA/HQ-84-28971 MDA903-84-C-0031 F/G 4/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

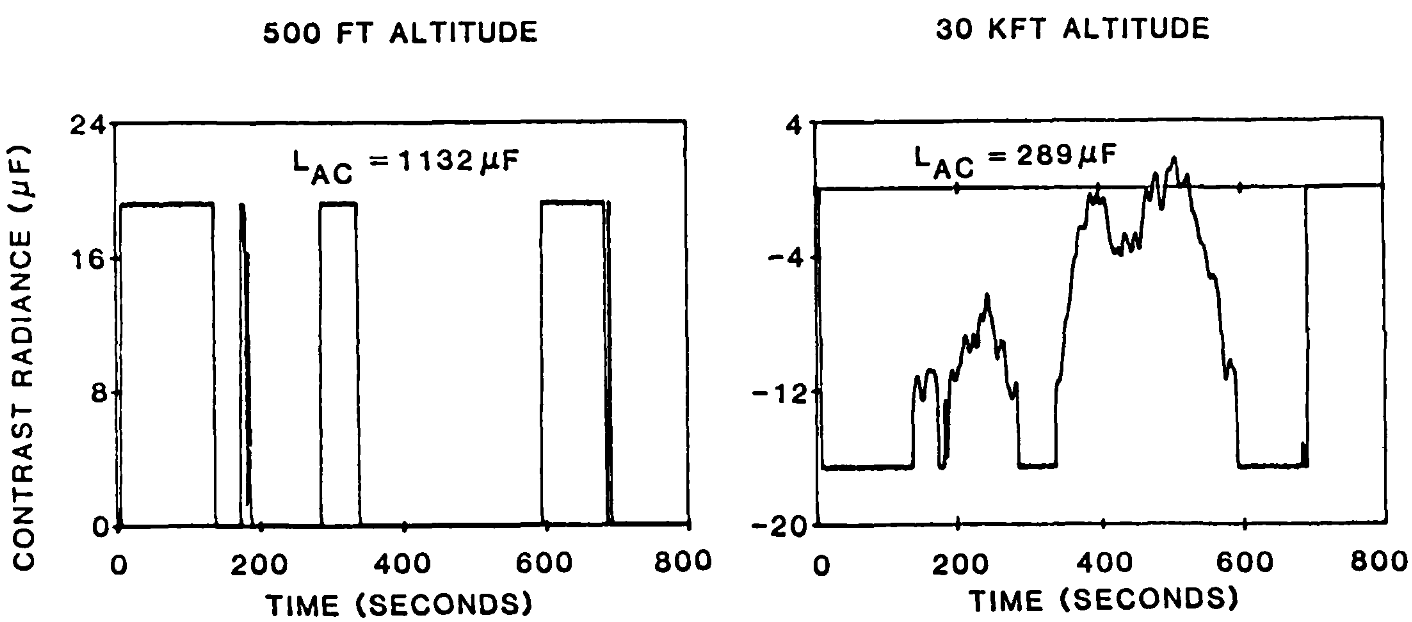
PRA

AIRCRAFT FLYTHROUGH TRACKS

LOW CLOUD

HIGH CLOUD

LWIR FLYTHROUGH CONTRASTS
HIGH CLOUD SCENE



PRA

DARPA CLOUD INTERESTS

(NOT WORKSHOP REQUESTS)

- CLOUD DATA BASE ISSUES
  - -- High Spatial Frequency Texture, Edge Gradients, and Cirrus; Being Currently Addressed by HI-CAMP II Program
  - -- Temporal Variations and Probability of Clutter Occurrence; Remain Unresolved
- CLOUD SCENE SIMULATION ISSUES
  - -- High View Angle and Cirrus PCFLOS, and Deterministic Spatial Representations; Being Currently Addressed
  - -- Near Real Time Cloud Cover Forecasting, and Irregular Surface Radiative Transfer Solution; Remain Unresolved
- DARPA REFERENCE SCENE EFFORTS CONTINUE
- WORKING RELATIONSHIP BETWEEN DARPA AND TRI-SERVICE CLOUD WORKSHOP SUGGESTED TO ASSIST IN TECHNOLOGY TRANSFER FROM DARPA TO SERVICES

EVALUATION OF THE EFFECTS OF CLOUDS ON SBL APPLICATIONS

Ronald J. Nelson
Science Applications, Inc.

Evaluation of the Effect of Clouds on SBL Applications

Ronald J. Nelson
Science Applications, Inc.

Abstract

Conventional wisdom has long held that the atmosphere and its phenomena, and clouds in particular, could act to reduce the potential utility of space based laser (SBL) weapon systems in defensive or offensive roles against endo-atmospheric targets. In 1980 a study was commissioned with the objective of determining the various ways in which clouds could effect SBL applications against long range bombers. The results showed that the problem was complicated but that the magnitude of the problem could probably be scoped using some reasonable - and, more importantly, traceable - assumptions. This paper presents the status of a follow on to the 1980 study.

Individual clouds, like the atmosphere itself, scatter and absorb radiation passing through them. However, clouds act almost as discontinuities in an otherwise relatively homogeneous medium so that, for many practical purposes, clouds can be treated as if they were infinite attenuators. In this sense, it is sufficient to know whether or not a cloud is in the line of sight between a potential target and an SBL. However, clouds are also sources of radiation. The radiation coming from individual cloud elements is in sharp contrast to that coming from areas immediately adjacent to the boundary of an individual element. Basically, the background radiance is blocked by the cloud element (assuming infinite attenuation) which makes its own, generally lower intensity, contribution to the total energy impinging on the SBL sensor aperture.

The principal objective of this effort is the development of a quantitative, first-order estimate of the effect of clouds on the potential utility of a space based laser weapon system used against a specific set of airborne and ground based targets taking into account the effect of clouds on the overall weapon system, i. e., on both the laser beam and the sensor.

The presentation will provide an overview of the logic used to accomplish the ojbective, including a review of the logic, analysis methodology and data analysis accomplished to date. This is a companion paper to the one being presented by Dr. J. L. Griggs.

The presentation is classified SECRET.* Time requested is 20 minutes not including time for questions and answers.

*Only the UNCLASSIFIED briefing charts presented at the workshop are included here.

EVALUATION OF THE EFFECT OF CLOUDS ON SPACE BASED LASER APPLICATIONS

RONALD J. NELSON

26 JUNE 1984

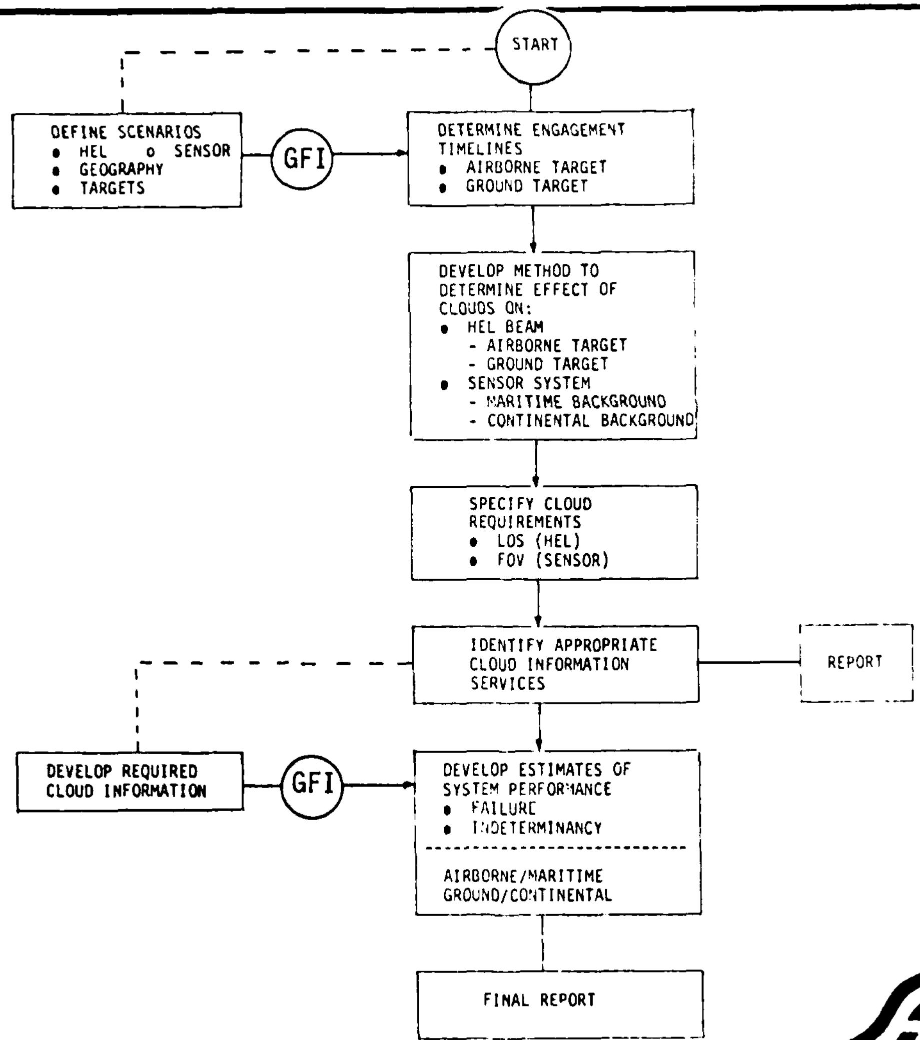
Science Applications, Inc.

OBJECTIVE

DEVELOP ESTIMATES OF THE PROBABLE UTILITY OF A SPACE BASED LASER WEAPONS SYSTEM EMPLOYED AGAINST AIRCRAFT OR BALLISTIC MISSILE TARGETS

Science Applications, Inc.

PROGRAM FLOW - TI-83-13



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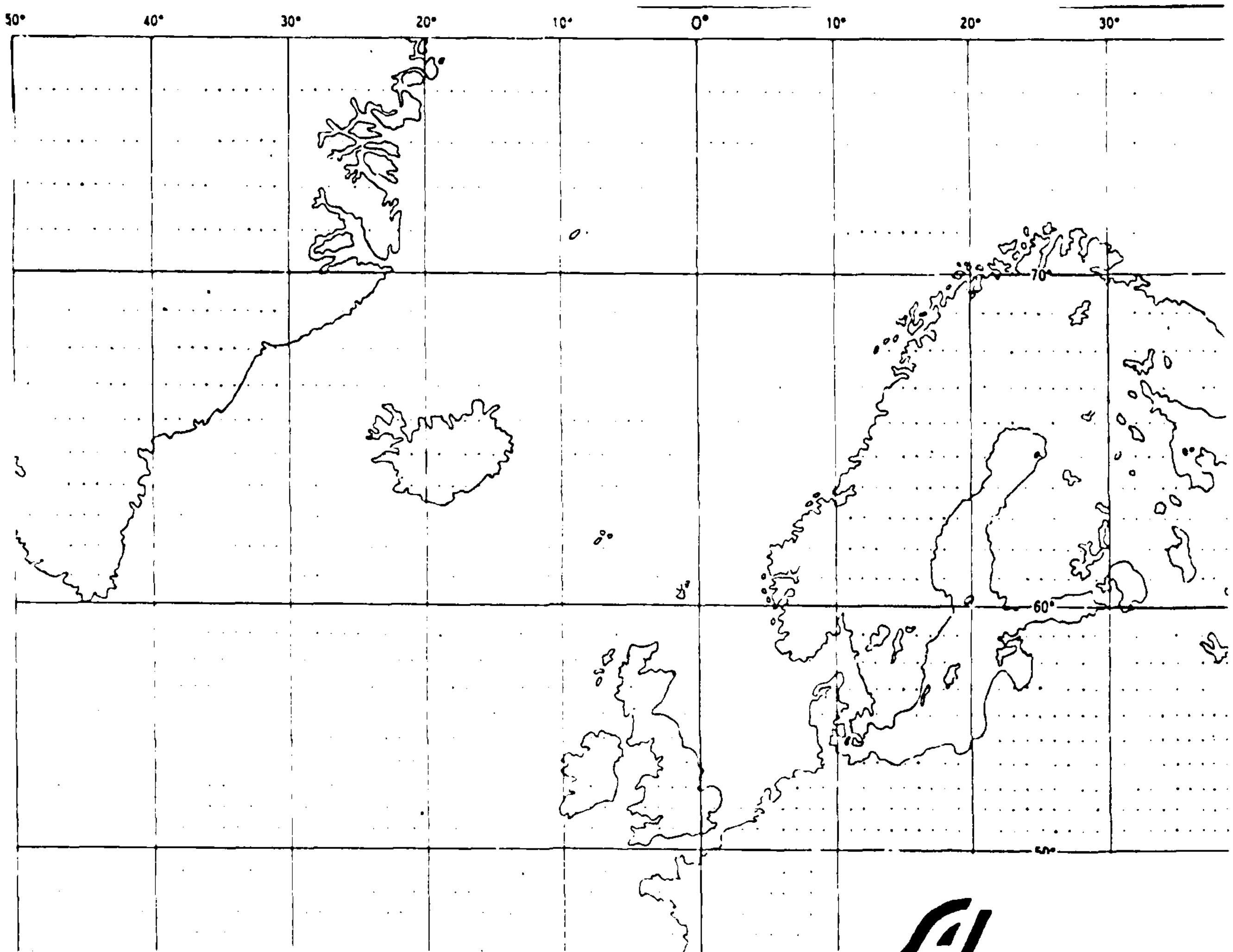
REGION OF INTEREST



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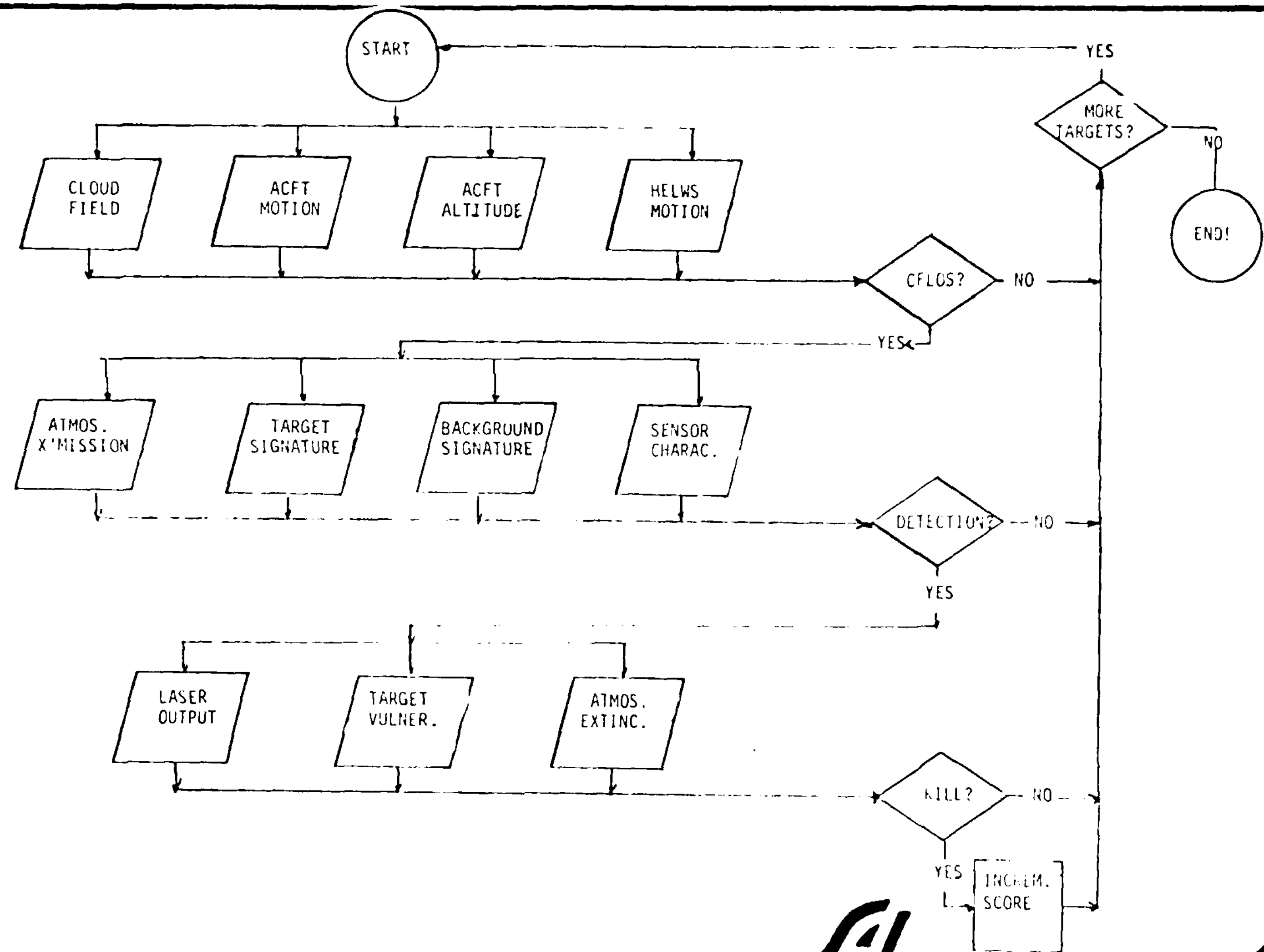
CONCEPTUAL LASER EFFECTIVENESS MODEL



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KILL ASSESSMENT

$$\# \text{ OF KILLS} = \text{INT}((\text{CFS}/V - T_{SENSOR})/(T_{SWITCH} + T_{KILL}))$$

Science Applications, Inc.

CLOUD INFORMATION SOURCES

- o CLOUD MODELS
- o CLIMATOLOGY
- o SATELLITE IMAGERY

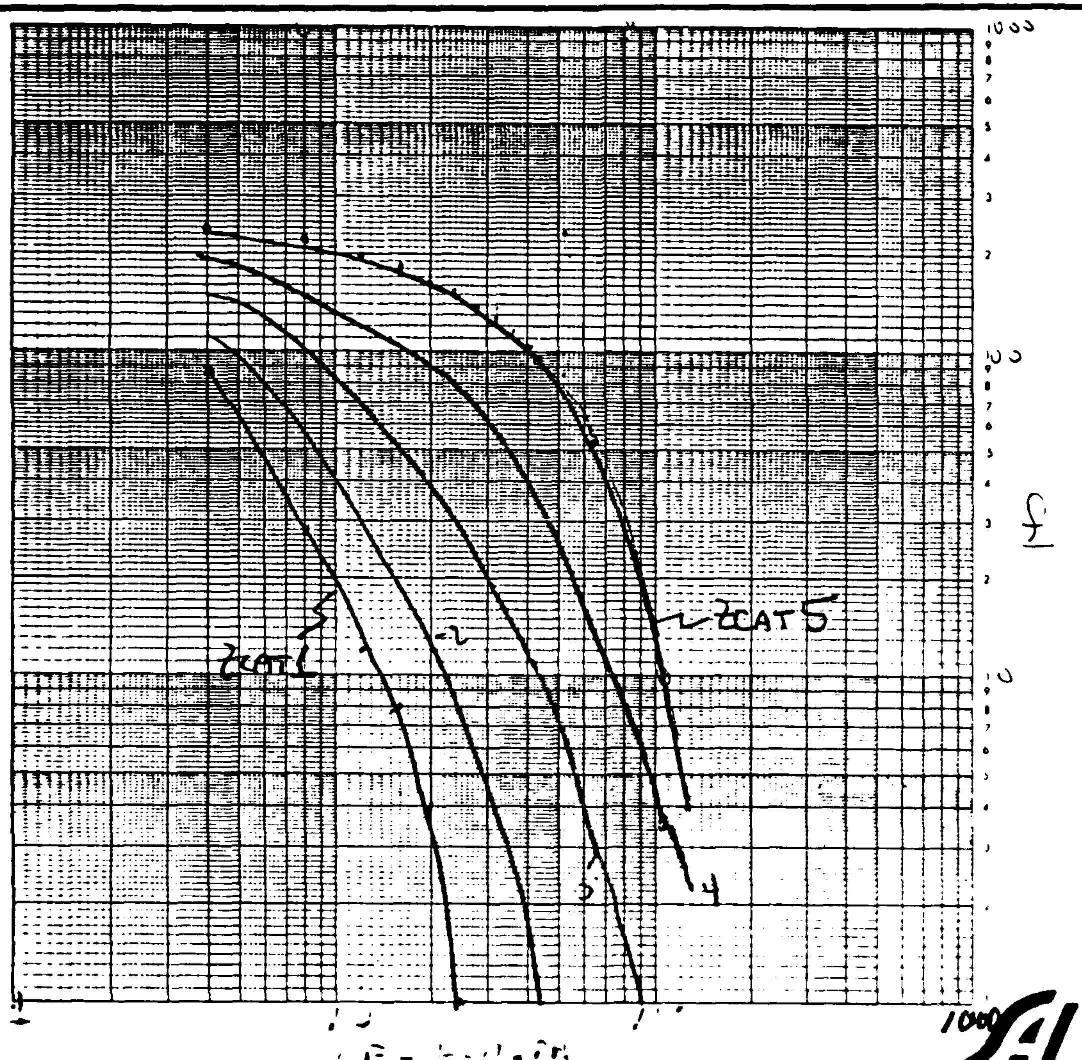
Science Applications, Inc.

DATA SELECTION PROCESS

- o VISUAL EXAMINATION OF SATELLITE IMAGERY
- o "WIDESPREAD CLOUDINESS" SUBSET OF IMAGES SELECTED
- o IMAGES GIVEN TO METSAT, INC. FOR FURTHER ANALYSIS

Science Applications, Inc.

CFS SPACE AS A FUNCTION OF HEIGHT CATEGORY



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MARITIME (BOMBER) SCENARIO - ATLANTIC N. OF 60^{O}N, BARENTS SEA

PRIMARY CLOUD CLIMATOLOGIES

- o ATLAS: MESERVE, U.S. NAVY MARINE CLIMATIC ATLAS OF THE WORLD, VOL. I, NORTH ATLANTIC OCEAN, DEC. 1974 (TDF-11)
- o OCAMO: DEVIOLINI, ET-AL, SEASONAL CLOUD AMOUNT AND CLOUD-FREE LINE-OF-SIGHT DATA FOR *. (3DNEPH)
  - * OCEANIC AREA EAST OF ICELAND TO THE FAROES (NA-2), AUG. 1980
  - * SOUTHERN BARENTS SEA (OA-1), SEPT. 1980
  - * NORWEGIAN SEA (NA-3), DEC. 1980
  - * DENMARK STRAIT (NA-1), JAN. 1981
- o NSWC: KATZ, ET AL, ESTIMATES FOR THE PROBABILITIES OF SURFACE-TO-AIR CLOUD-FREE LINES-OF-SIGHT AND LOW CLOUD STATISTICS FROM SHIP OBSERVATIONS, PART 1, FIFTEEN MARINE LOCATIONS, NOV. 1980 (OWS SFC. OBS)
- o NCAR: HAHN, ET AL, ATLAS OF SIMULTANEOUS OCCURRENCE OF DIFFERENT CLOUD TYPES OVER THE OCEAN, NOV. 1982. (NAVY CONSOLIDATED DATE SET)
- o AFGL: BERTONI, CLEAR- AND CLOUD-FREE LINES-OF-SIGHT FROM AIRCRAFT, AUG. 1977. (AIRBORNE OBSERVATIONS)

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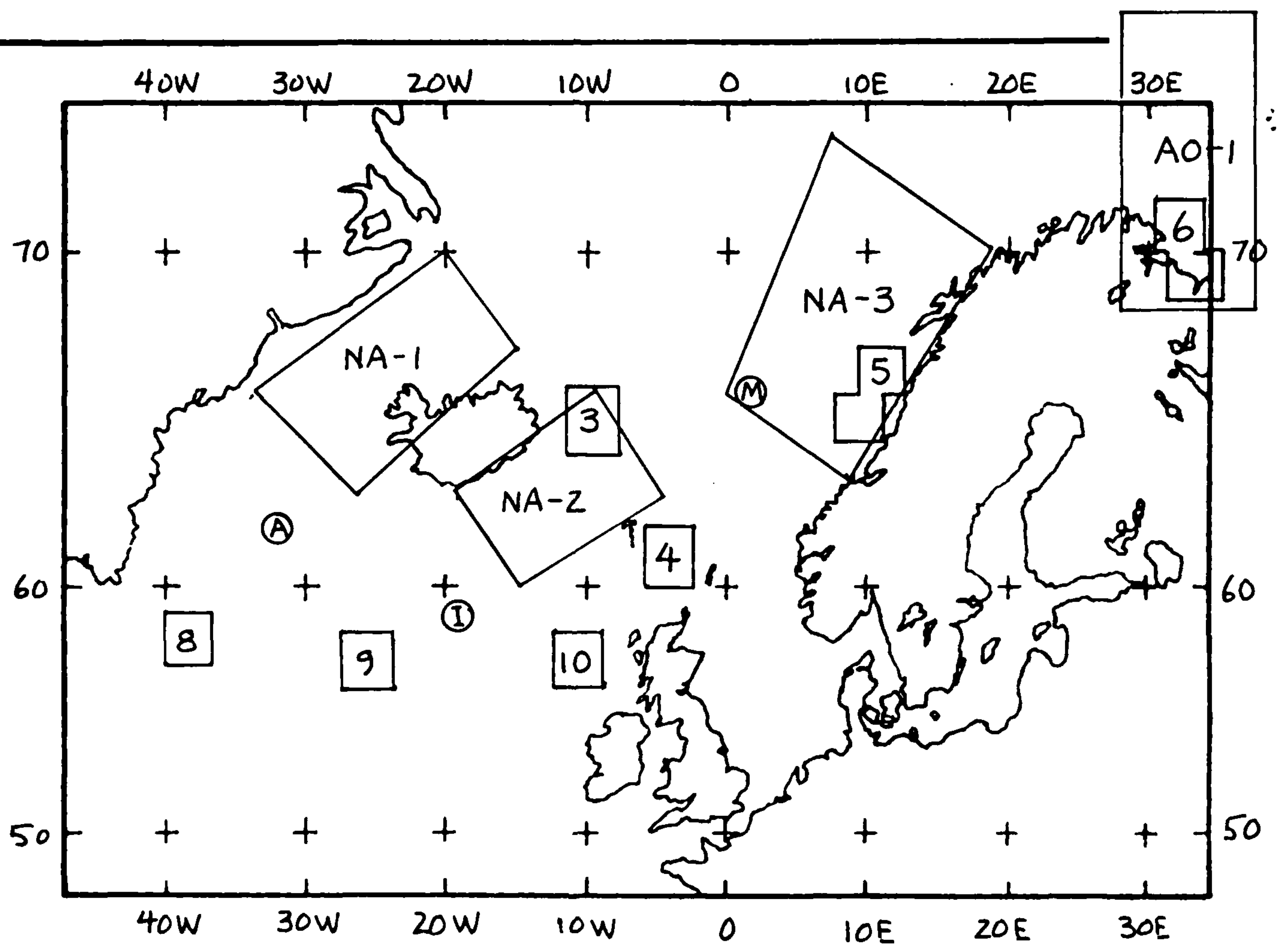
DATA POINT & AREA LOCATIONS FOR ATLAS, OCAMO, NSWC



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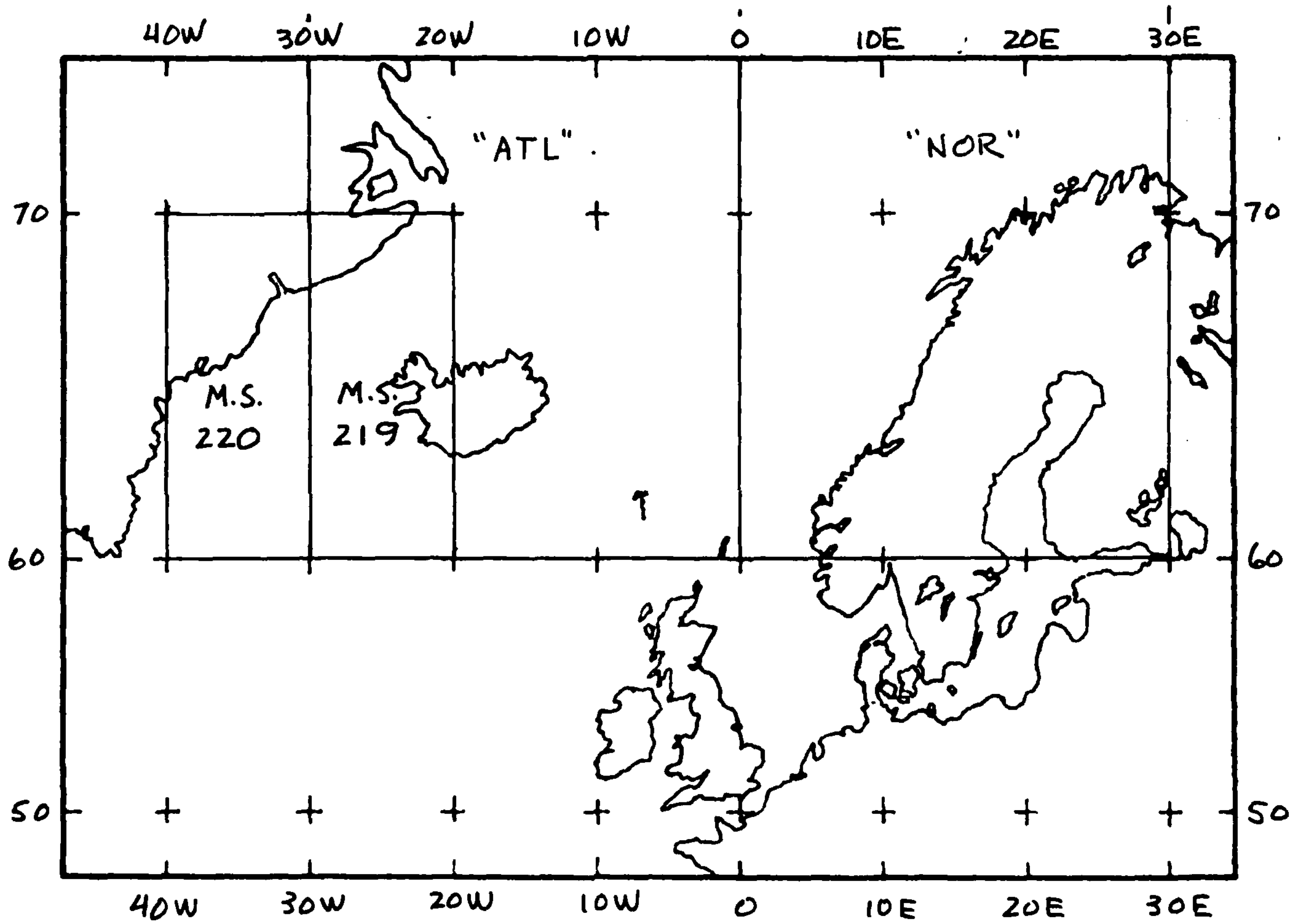
DATA AREA LOCATIONS FOR NCAR, AFGL



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FIRST-ORDER ASSESSMENTS

- "GUARANTEED SUCCESS" -- CLEAR SKIES
- "GUARANTEED FAILURE" -- SINGLE LAYER OVERCAST
- MULTI-LAYER FREQUECY AND CHARACTERISTICS
- PREFERRED CLOUD LAYER ALTITUDES

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"GUARANTEED SUCCESS" -- CLEAR SKIES

RANGES OF VALUES

	ATLAS PR(N_T=0/8)	OCAMO PR(N_T=0/10)		NSWC FREQ (NO CLOUDS)	NCAR PR (NO CLOUDS)
JAN	<.01-.04	.04-.11	WINTER	.006-.011	.02
AFR	<.01-.06	.06-.16	SPRING	.008-.038	---
JUL	<.01-.04	.07-.16	SUMMER	.004-.028	.01-.02
OCT	<.01-.03	.04-.09	FALL	---	---

FIRST ORDER ASSESSMENT: ESSENTIALLY ZERO PROBABILITY OF CLEAR SKIES OVER A WIDE AREA OR LONG PATH.

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"GUARANTEED FAILURE" -- SINGLE LAYER OVERCAST

	TOTAL CLOUDS					LOW CLOUDS, ONLY	
	ATLAS $PR(N_T=8/8)$		OCAMO $PR(N_T=10/10)$			NSWC $PR(N_L=8/8)$	
	RANGE	AVG	RANGE	AVG		RANGE	AVG
JAN	.32-.60	.46	.30-.40	.35	WINTER	.21-.32	.25
APR	.23-.60	.41	.34-.42	.38	SPRING	.18-.34	.26
JUL	.35-.73	.52	.29-.40	.35	SUMMER	.30-.39	.33
OCT	.31-.51	.42	.37-.44	.40	FALL	---	---

FIRST ORDER ASSESSMENT: SMALL BUT SIGNIFICANT (.05 TO .15) PROBABILITY OF OVERCAST SKIES OVER A WIDE AREA OR LONG PATH.

Science Applications, Inc

MULTI-LAYER FREQUENCY & CHARACTERISTICS: SUMMARY

- MULTIPLE LAYERS OCCUR ≈ 65% OF TIME
- LOW CLOUDS DOMINATE -- PRESENT ≈ 85% OF TIME
- MIDDLE AND HIGH CLOUDS MOSTLY OCCUR IN MULTI-LAYER SITUATIONS
- HIGH CLOUDS ARE LEAST PREVALENT (≈30% OF TIME)

FIRST ORDER ASSESSMENT: HIGH FREQUENCY OF MULTIPLE LAYERS COMPLICATES SBL ANALYSIS PROBLEM -- SOMEWHAT MITIGATED BY LOW-CLOUD DOMINANCE.

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CLOUD MODELING EFFORTS AT THE NAVAL ENVIRONMENTAL PREDICTION RESEARCH FACILITY

Paul M. Tag
Naval Environmental Prediction
Research Facility

TABLE 1

SALIENT FEATURES OF CANDIDATE NUMERICAL MODELS

MODEL	TURBULENCE	RADIATION	SURFACE FLUX	RADIATION FROM ABOVE BOUNDARY LAYER	SUBSIDENCE
ARAP	Higher Order Closure Prognostic Eqs. for 2nd Order Moments	ARAP Package; Cloud Droplet Scattering for Short Wave	Surface Similarity Approach	Yes	Yes
Burk	Higher Order Closure Prognostic Eqs. for 2nd Order Moments	ARAP Package; No Cloud Droplet Scattering for Short Wave	Surface Similarity Approach	Yes	Yes
NPS	Well-mixed Slab Model	Long wave emissivity from liquid water; Delta-Eddington Short Wave	Bulk Aerodynamic Approach	Yes	Yes
Tag	K-theory: Eddy Coefficient function of local wind shear and bouyancy	ARAP Package; Cloud Droplet Scattering for Short Wave	Surface Similarity Approach	Yes	Yes (only in 1-D mode)
Wurtele	Eddy Coefficient function of turbulent kinetic energy and scale length, local wind shear and bouyancy	Emissivity radiative transfer model	Bulk Transfer coefficients from surface similarity	Yes	Yes

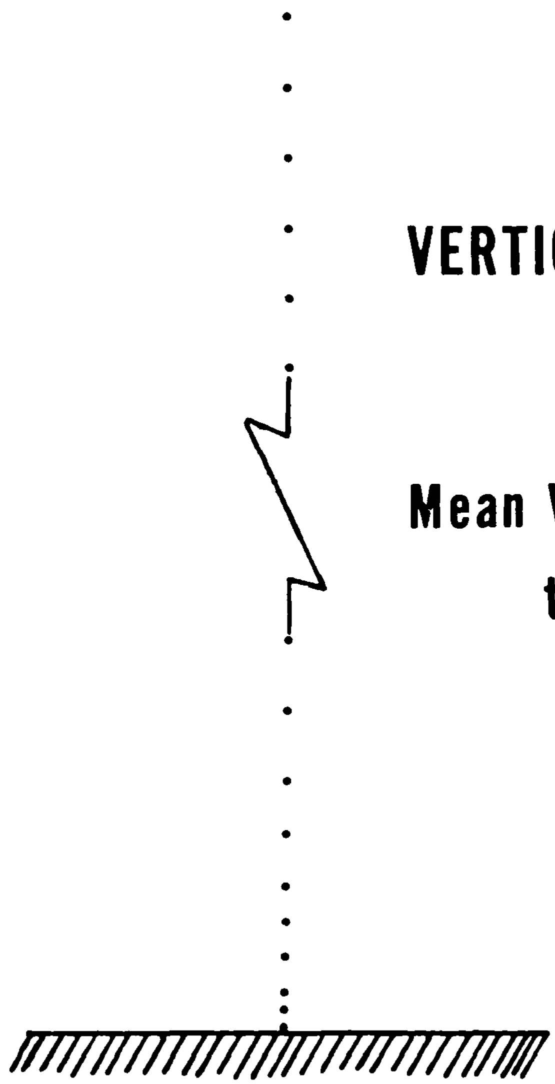
16

Table 2'

SUMMARY OF DATA SETS

Case	Type	Time Interval	Time of Day	Low Level Temp Structure	Initial Cloud	Winds	Synoptic Scale Vertical Motion	Sea Surface Temp: Relative to Air	Sea Surface Temp: Trend with Distance
Aug 29, 1972 Case 6	Stratus* lowering to fog	3 hr	Evening	Neutral	Yes	lt.	zero	cold	---
July 14-15, 1973 Case 4	Stratus thickening	10	Night	Neutral	Yes	lt.	zero	warm	constant
May 22, 1978 Case 1	Stratus	4	Morning	Unstable to Neutral	Yes	mod.	zero	warm	warming
Aug 2, 1975 Case 2	Shallow cold water advection fog	3	Evening	Inverted	No	mod.	----	cold	cooling
Aug 5, 1975 Case 5	Shallow cold water fog deepening over warm water	3	Morning	Inverted to Isothermal	No	mod.	----	cold to warm	warming
Oct 7, 1976 Case 3	Thinning stratus re-developing to form fog	10, . 20	Morning to Night	Neutral to Unstable	Yes	lt.	strong subsidence	warm	warming

MODEL STRUCTURE



VERTICAL 'TOWER' OF GRID POINTS

Mean Values: U, V, T, q, Q_L

turbulence quantities

Diagnose: M

CASE 5

5 August 1975

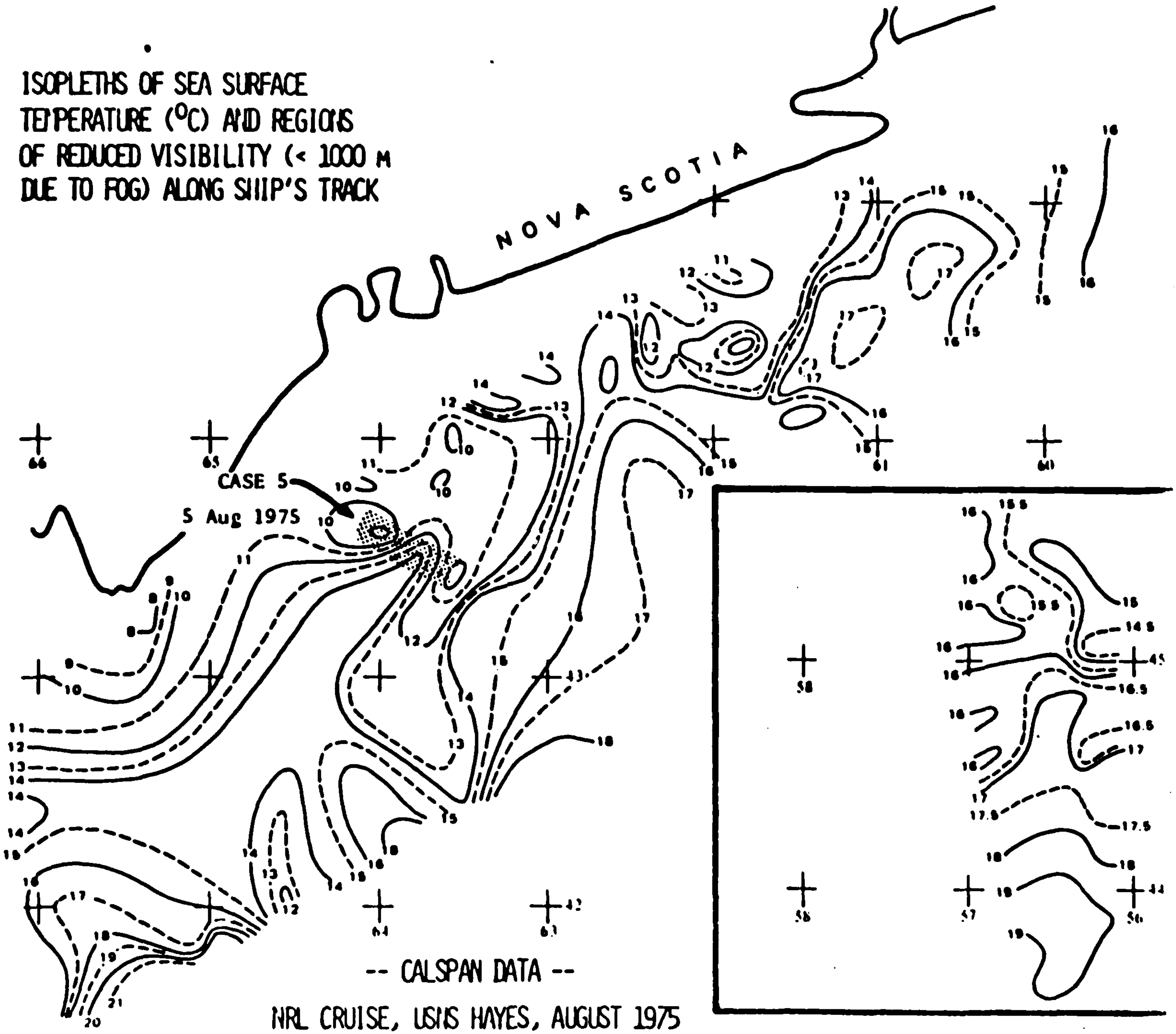
Off Southeast Coast of Nova Scotia
(~80 km offshore)
(USNS HAYES Marine Fog Cruise)

Time Zero: 0600 EDT

Simulation Times: 3 hours

Sunrise: 0500 EDT

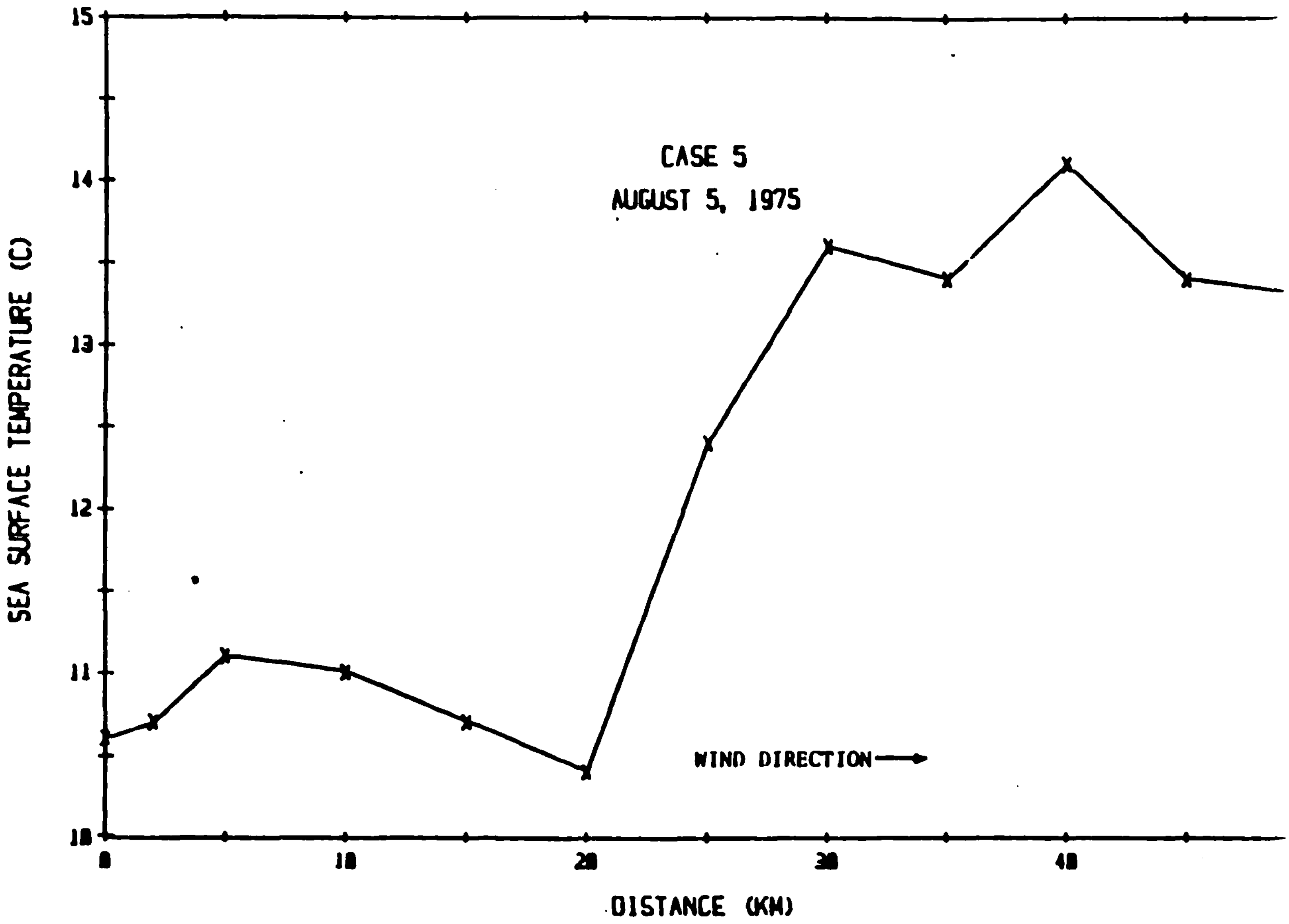
Scenario: Shallow advection fog formed over cold water, dramatically increased in depth farther downwind over substantially warmer water.



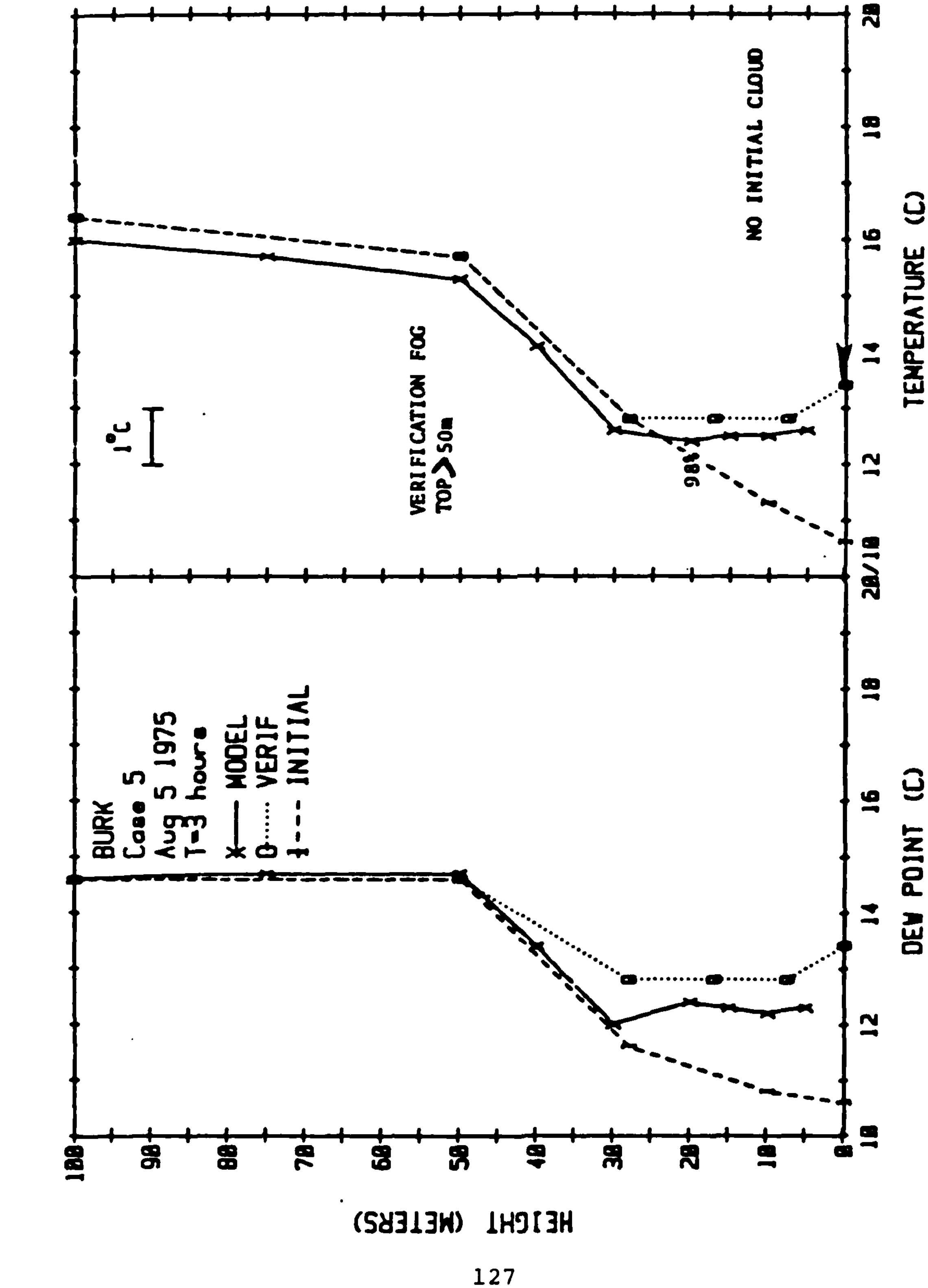
ISOPLETHS OF SEA SURFACE TEMPERATURE (^{o}C) AND REGIONS OF REDUCED VISIBILITY (< 1000 M DUE TO FOG) ALONG SHIP'S TRACK

-- CALSPAN DATA --

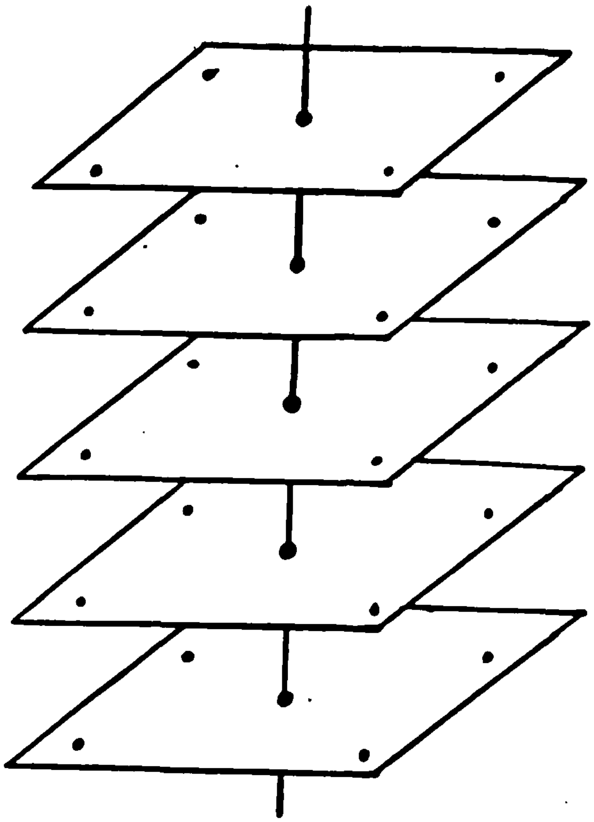
NRL CRUISE, USNS HAYES, AUGUST 1975



CASE 5
AUGUST 5, 1975
SEA SURFACE TEMPERATURE (C)
15
14
13
12
11
10
0
10
20
30
40
DISTANCE (KM)
WIND DIRECTION


BURK
Case 5
Aug 5 1975
T=3 hours
MODEL
VERIF
INITIAL
NO INITIAL CLOUD
VERIFICATION FOG
TOP > 50m
98%
1°C
HEIGHT (METERS)
DEW POINT (C)
TEMPERATURE (C)

NAVY OPERATIONAL LOCAL ATMOSPHERIC PREDICTION SYSTEM (NOLAPS)



- NOLAPS consists of a 1-D, "Level-3" higher order closure model run at open ocean sites
- NOLAPS uses NOGAPS analysis and forecast fields to compute large scale advective terms
- NOLAPS provides a high-resolution forecast of PBL behavior

Nose Cone Erosion =

f(Cloud Liquid Water Content (LWC) as a function of height)

Problem: What is the LWC versus height at the point of interest?

Possible Data Base: The Air Force 3DNEPH (RTNEPH): a global nephanalysis at a grid resolution of 25 nm.

Problem: Although the 3DNEPH (RTNEPH) provides cloud type vs. height, it does not provide detailed microphysical data (e.g., LWC)

Possible Solution: Use the Smith - Fedder model to diagnose microphysical characteristics of the 3DNEPH (RTNEPH) clouds.

What is the Smith-Fedder Model?

The Smith-Fedder Model is a diagnostic tool to determine at a point on the earth's surface the type and location of suspended water aloft. Specifically, it diagnoses

1. Condensed moisture content
2. Its thermodynamic phase
3. The particle size distribution

The input parameters are as follows:

1. Low, middle, high, or convective cloud types - 3DNEPH
2. Layered cloud amounts - 3DNEPH
3. Present weather conditions - 3DNEPH
4. Base, tops, and midpoints of layers - AFGWC Model Terrain
5. Temperature and D-value profiles - (USAFETAC TN 74-2 - Appendix B)

How is NEPRF contributing to this scheme?

NEPRF has assumed responsibility for the following:

1. Convert the Smith-Feddes model from the 3DNEPH to the RTNEPH format.

2. Direct and evaluate all of the micro-physical analysis in the model. Update these portions with the latest cloud physical data.

3. Implement the Smith-Feddes model to run on the Fleet Numerical Oceanographic Center (FNOC) computers.

STRATUS BREAKUP INTO STRATOCUMULUS

DEARDORFF: $\Delta\theta_e < (\Delta\theta_e)_{crit}$

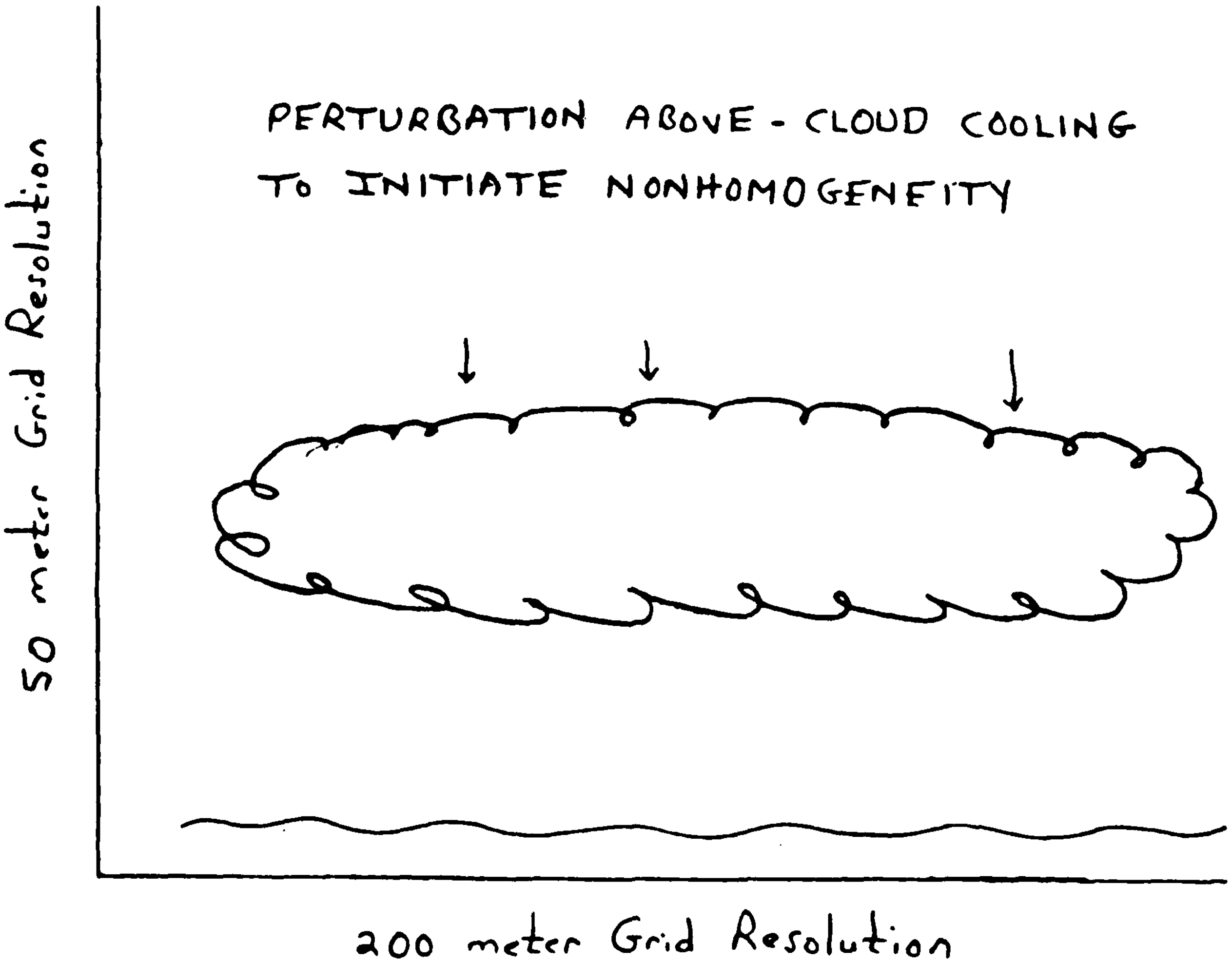
where $(\Delta\theta_e)_{crit} = \dfrac{\bar{\theta}\,\Delta q_w}{\alpha}$

and $\theta_e = \theta\left(1 + \dfrac{L}{C_p T} q\right)$

QUESTION ONE: CAN THE ABOVE CRITERIA ACCURATELY PREDICT WHEN A STRATUS DECK WILL BREAK UP?

QUESTION TWO: CAN THIS SAME CRITERIA BE SUCCESSFULLY APPLIED OVER AN AREA TYPIFIED BY THE GRID SPACING IN A GLOBAL MODEL?

HIGH RESOLUTION NUMERICAL SIMULATION OF STRATUS BREAKUP



TRIDENT TARGETING AND TEST FLIGHT ANALYSES

Susan Masters
Naval Surface Weapons Center

TRIDENT II

MISSILE SYSTEM

REENTRY BODY CLOUD ENCOUNTER

- MECHANICAL NOSETIP DEFORMATION
- BODY DEMISE
- ACCURACY REDUCTION

SOLUTIONS ?

- PRELAUNCH TARGETING COMPENSATION
- INSENSITIVE REENTRY BODY

TARGET OFFSETS

- CLOUD PARTICLE DESCRIPTORS
  - TYPE
  - NUMBER
  - SIZE DISTRIBUTION
  - ALTITUDE
- CORRELATED PERFORMANCE EFFECT

TARGET OFFSETS

- NO OPERATIONAL PRODUCT PROVIDING EROSION CLOUD PARAMETERS IS AVAILABLE
- CLOUD PARAMETERS NEEDED FOR EROSION ANALYSIS ARE NOT REGULARLY MEASURED
- USAF NEPHANALYSIS PROVIDES THE ONLY SYSTEMATIC OPERATIONAL CLOUD PRODUCT

CLOUD PARAMETERS

- USAF SMITH/FEDDES MODEL CONSTRUCTS LIQUID WATER PROFILE BASED ON NEPHANALYSIS, TEMPERATURE, AND NOMINAL CLOUD TYPE/LWC CORRELATIONS
- NSWC CONSTRUCTED EURASIAN DATA BASE (22 SITES, 1 YEAR)
- NEPRF WILL CONVERT S/F TO USE RTNEPH DATA AND DETERMINE POSSIBLE IMPROVEMENTS

CLOUD PARAMETERS

- NEPRF IS CONTINUING TO INVESTIGATE FFT CLOUD IDENTIFICATION METHOD

- SUCCESSFUL FFT TECHNIQUE WOULD PROVIDE A TOOL FOR MORE DETAILED AUTOMATED CLOUD ANALYSES

- NEPRF IS CONSTRUCTING DATA BASES FOR FURTHER FFT EVALUATION

IN CONCLUSION

- NO TARGETING COMPENSATION FOR CLOUD EFFECTS BY IOC

- CONTINUING INVESTIGATION OF CLOUD ANALYSIS METHODS
  - ACCURACY ASSESSMENT
  - REENTRY FLIGHT TEST PERFORMANCE ASSESSMENT

SYNTHETIC CLOUD SCENES FOR IRST SENSOR DESIGN APPLICATIONS

Alex T. Maksymowicz
Lockheed Missiles and Space Company, Inc.

John H. Allen
Center for Defense Analysis
SRI International

SYNTHETIC CLOUD SCENES FOR IRST SENSOR DESIGN APPLICATIONS

Authors: Alex T. Maksymowicz
Org. 92-20, Bldg. 205
Lockheed Missiles & Space Company, Inc.
3251 Hanover Street
Palo Alto, CA 94304
Telephone: (415) 424-2635

John H. Allen
EJ33
Center for Defense Analysis,
SRI International
333 Ravenswood Avenue
Menlo Park, CA 94025
Telephone: (415) 859-2678

ABSTRACT

Deterministic synthetic cloud scenes in the 8-12 micrometer band have been generated for the side-looking viewing geometry characteristic of infrared search and track (IRST) scenarios. LANDSAT data were used as the point of departure for generating three-dimensional cloud morphology and liquid water content distributions. The integrated liquid water path was computed for each pixel in a 256 x 1024 pixel scene by projecting the line of sight through the three-dimensional cloud distribution. The liquid water path ,in turn, determined the value of the cloud radiance, using a model derived from a detailed multiple scattering treatment of radiative transfer in clouds.

A five-frame temporal sequence was generated for each of two scenes, a high cirrus layer and a cumulus layer. Each sequence corresponds to specific sensor motion, stare point, and interframe interval. Each frame represents a different projected view of the three-dimensional cloud distribution. Thus, the sequence displays differential motion effects between frames, wherein displacement of features depends on their distance from the sensor. This allows realistic simulation of sensor motion effects on signal processing operations.

Descriptions are given of the viewing scenarios, sampling parameters, and the statistical properties of the three-dimensional cloud and radiance distributions for each of the two scenes. To illustrate the application of the synthetic scenes to IRST sensor design efforts, pictorial examples are presented of these scenes, together with their focal plane images during various stages of a signal processing simulation.

SYNTHETIC CLOUD SCENES FOR IRST SENSOR DESIGN

Lockheed

ALEX MAKSYMOWICZ

(LOCKHEED RESEARCH LABORATORIES, PALO ALTO, CA 94304)

AND

JOHN H. ALLEN

(SRI INTERNATIONAL, MENLO PARK, CA 94025)

WORK SUPPORTED BY NADC, WARMINSTER, PA

(CONTRACT NO. N62269-82-C-0340)

PRESENTED AT

SECOND ANNUAL TRI-SERVICE CLOUD MODELING WORKSHOP

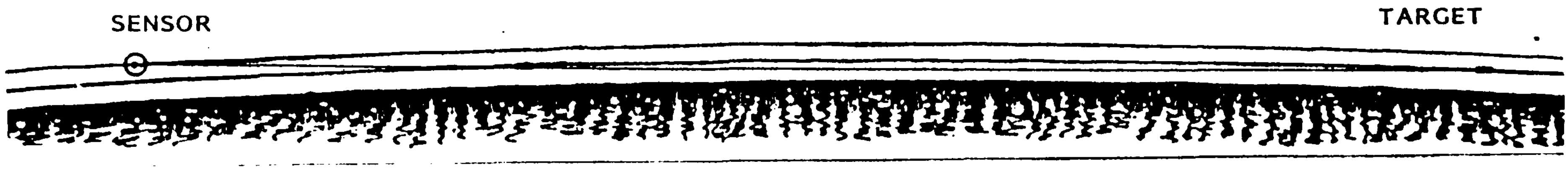
NAVAL SURFACE WEAPONS CENTER

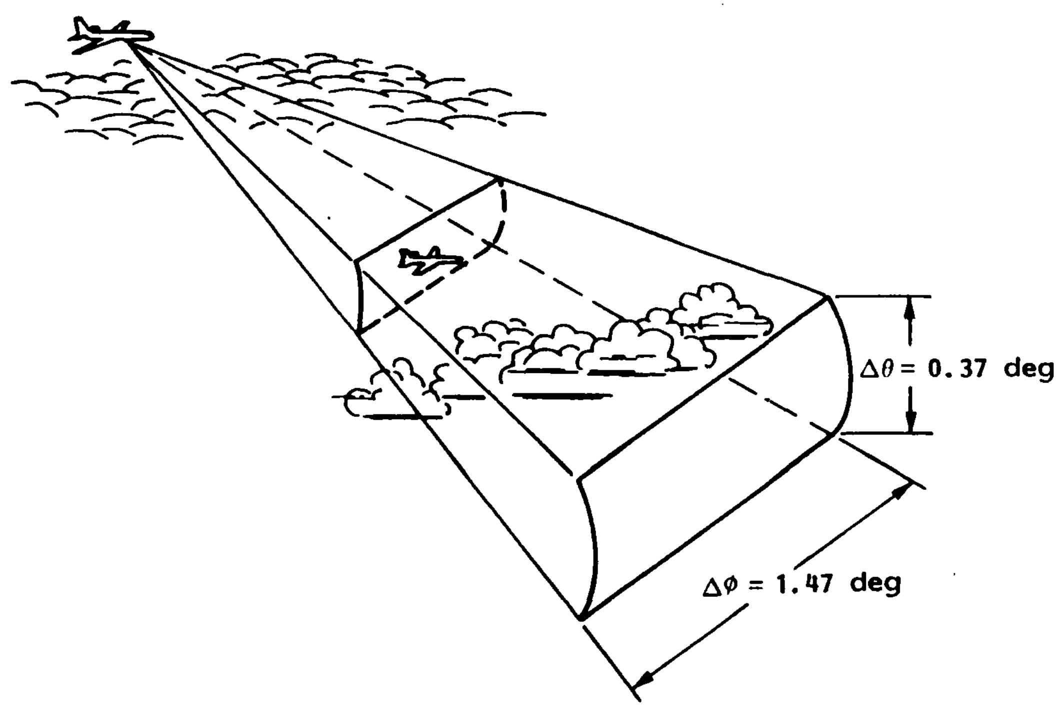
WHITE OAK, MD

26 JUNE 1984

Lockheed

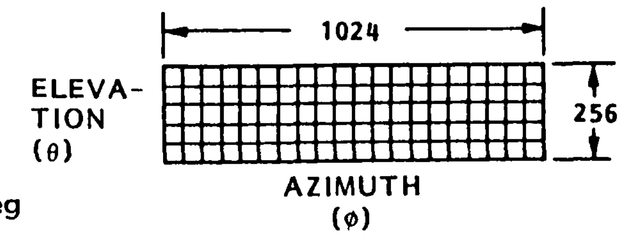
VIEWING GEOMETRY





SCENE PARAMETERS

FOV: 6.4 x 25.6 mrad



SAMPLE SPACING: 25 μrad

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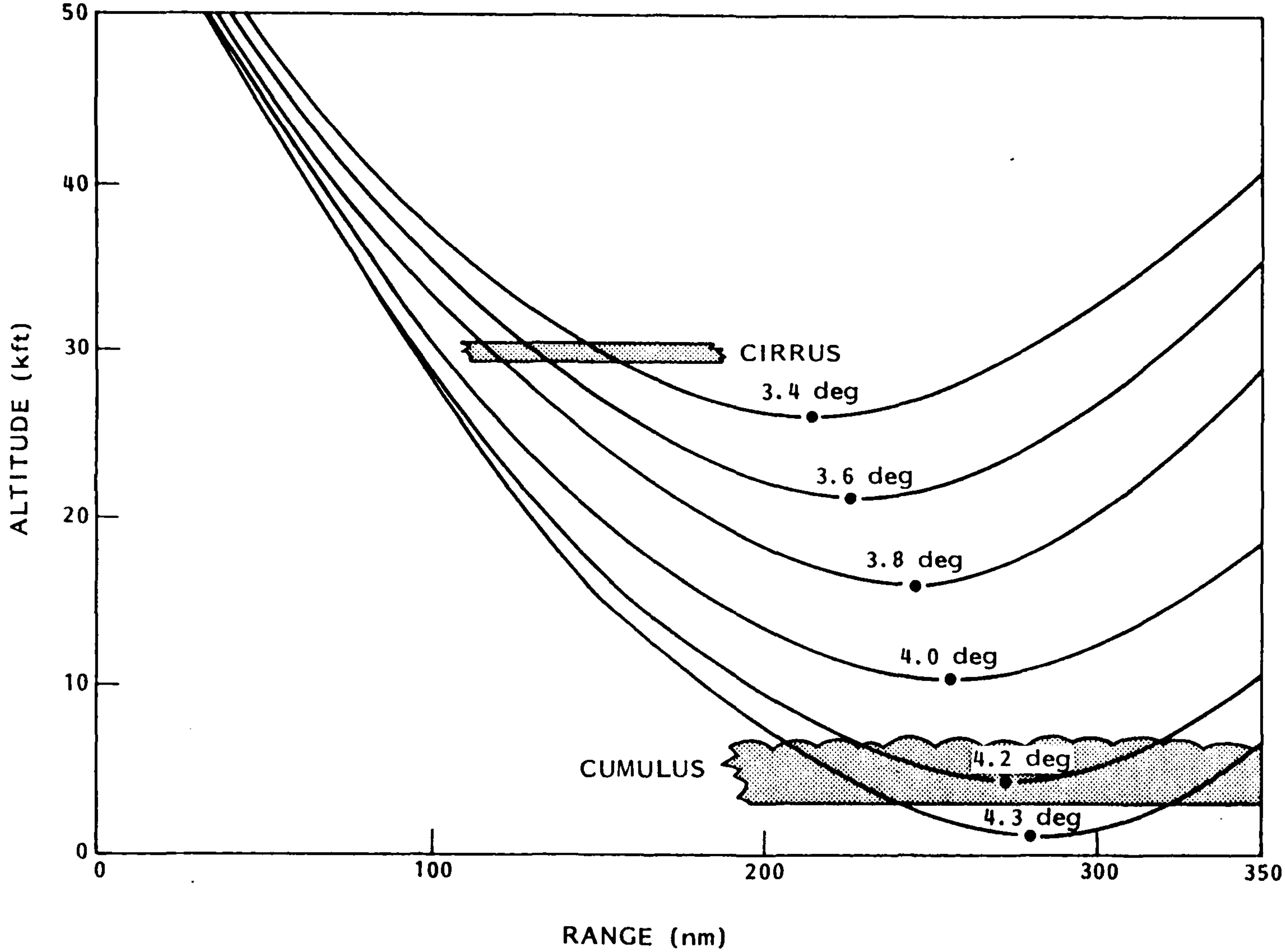
VIEWING SCENARIOS: ELEVATION VIEW



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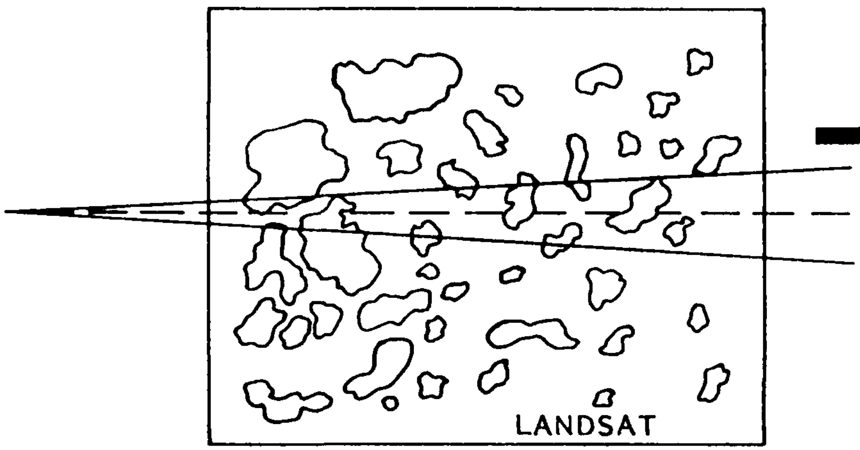
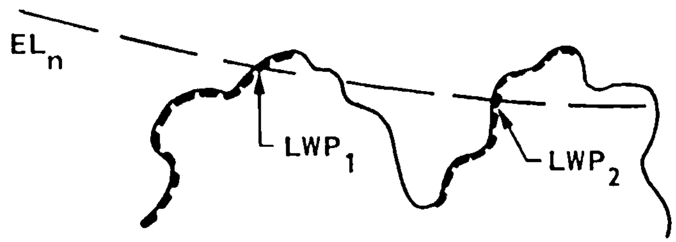
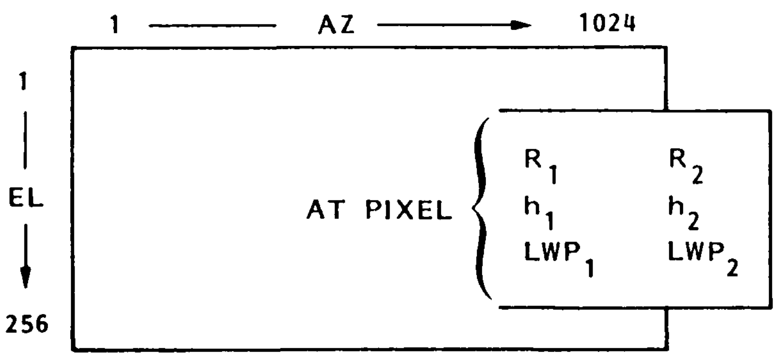
CLOUD MODEL



a. SELECTION OF CLOUD FIELD FROM LANDSAT PHOTOGRAPH



b. PROJECTION OF LINE-OF-SIGHT THROUGH CLOUD DISTRIBUTION



c. OUTPUT DATA FILE FORMAT

LIQUID WATER PATH:

$$LWP = \int_{\Delta s} ds\ \rho_L(s)$$

$LWP \rightarrow g/m^2$

$\rho_L \rightarrow g/m^3$

Δs = PATH LENGTH OF LOS INSIDE CLOUD

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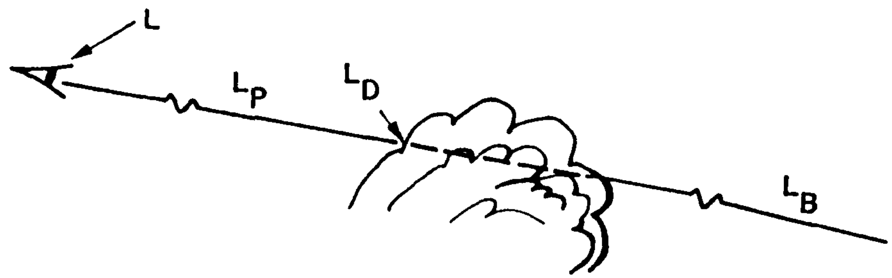
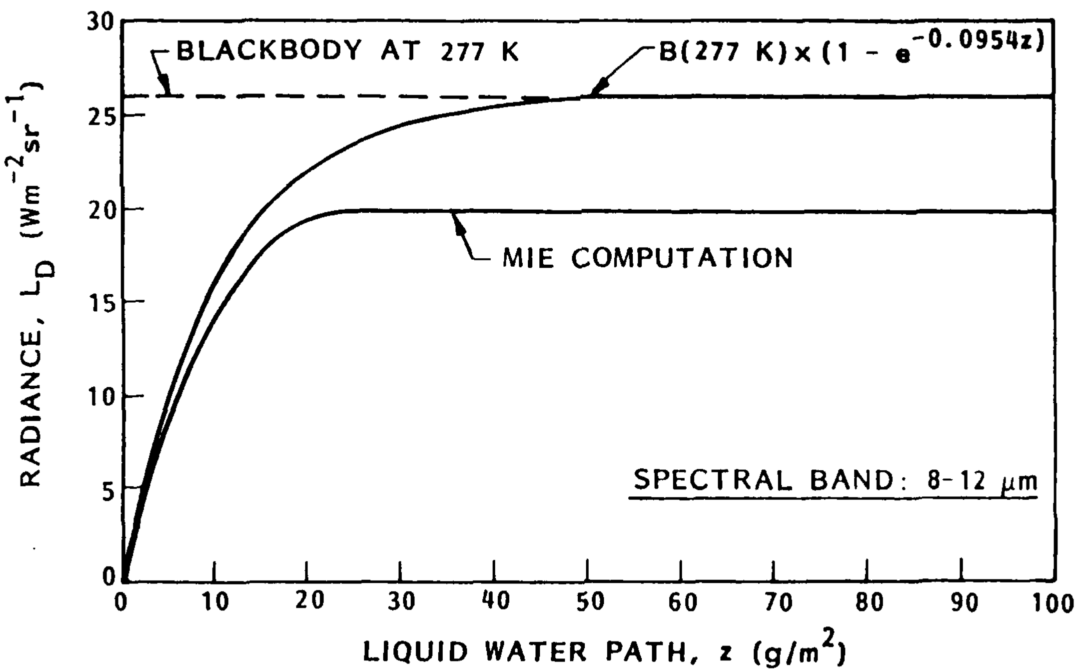
CLOUD RADIANCE

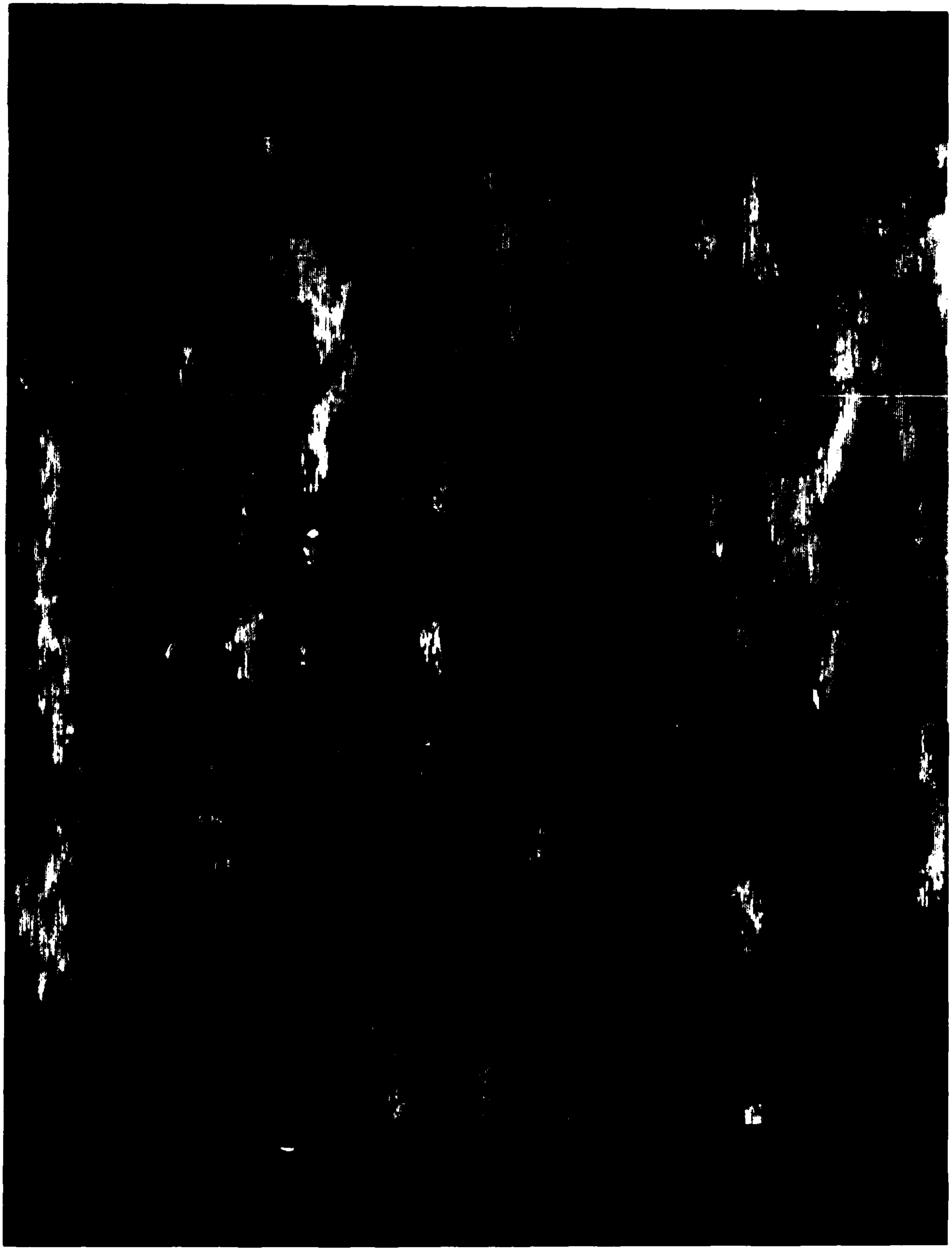


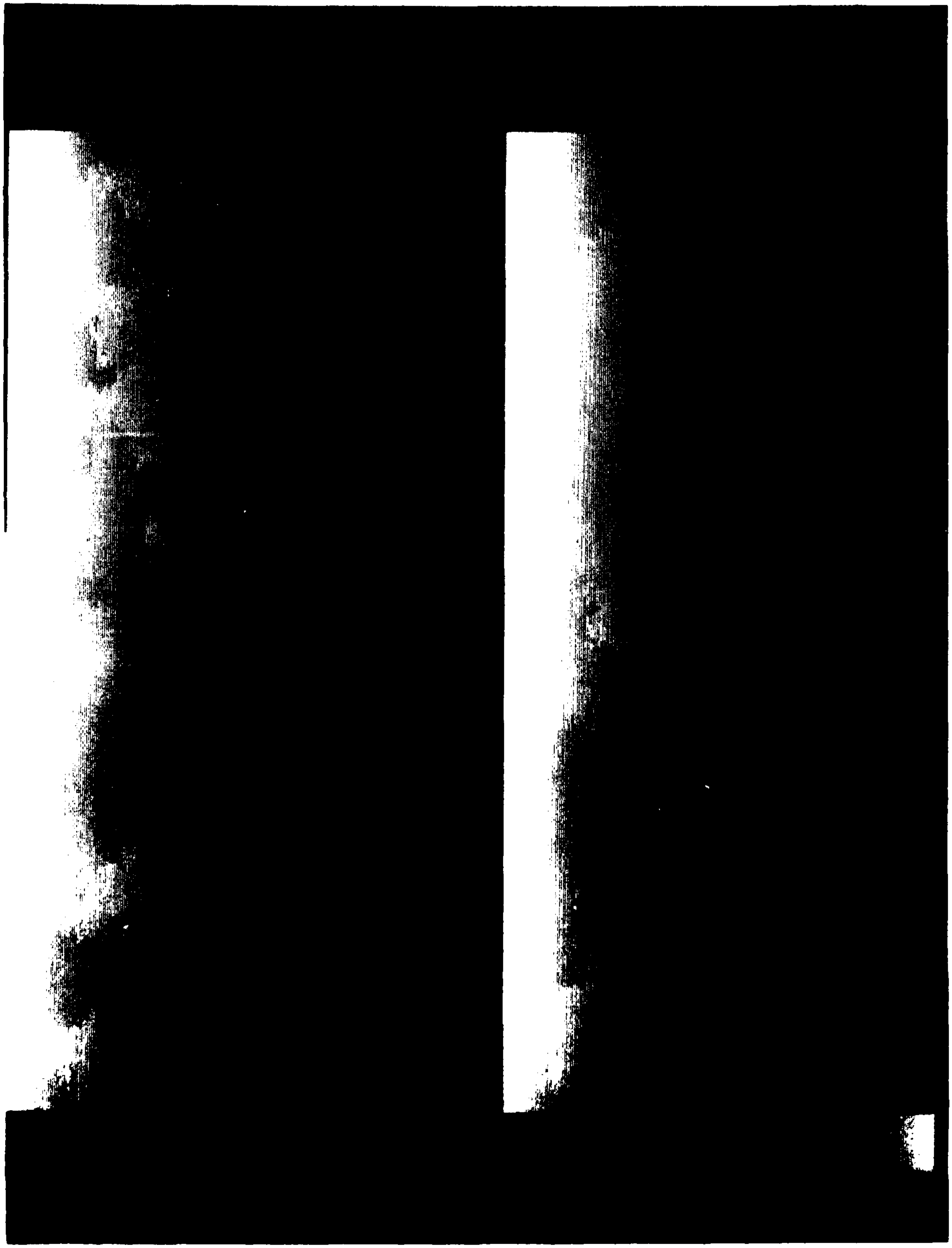
RADIATIVE TRANSFER

$$L = L_P + t_P \left(L_D + t_C\, L_B\right)$$



CUMULUS (ALTITUDE = 1.75 km)





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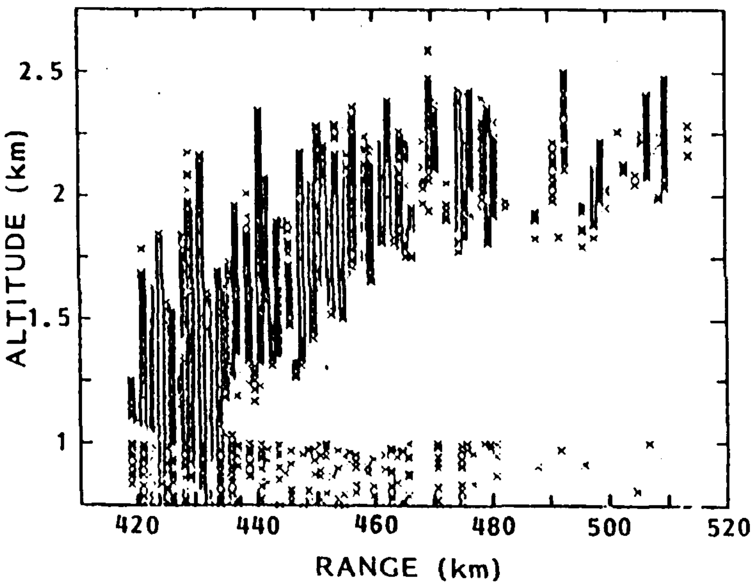
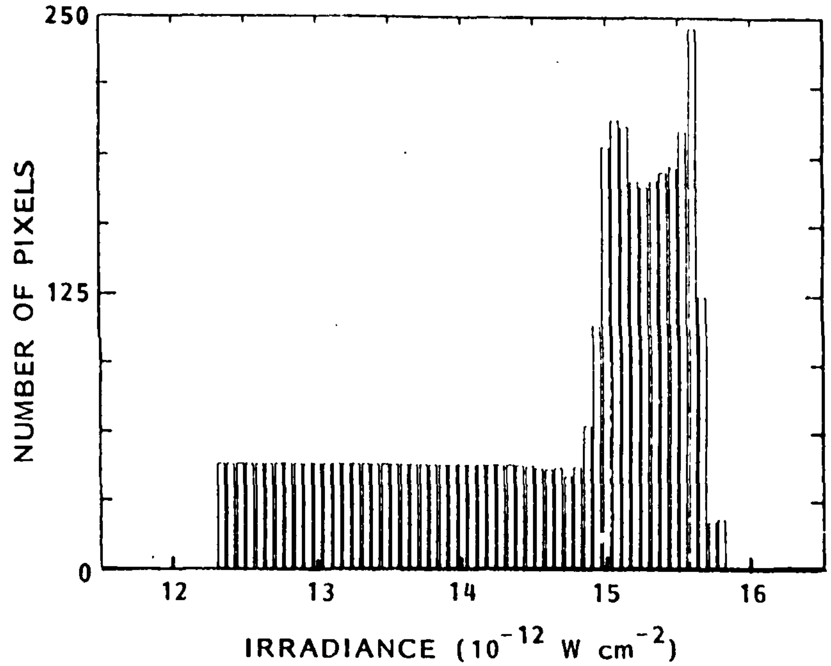
STATISTICAL PROPERTIES OF CUMULUS SCENE



MIN. RANGE	=	226 nm
MAX. RANGE	=	277 nm
MIN. ALTITUDE	=	2.90 kft
MAX. ALTITUDE	=	8.52 kft



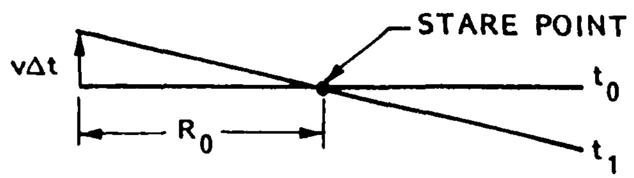
MIN.	=	12.3×10^{-12} Wcm^{-2}
MEAN	=	14.6×10^{-12} Wcm^{-2}
MAX.	=	15.9×10^{-12} Wcm^{-2}
STD. DEV.	=	1.01×10^{-12} Wcm^{-2}

(CLUTTER EQUIVALENT IRRADIANCE)

SCENE SEQUENCE

SENSOR MOTION: $v\Delta t$

($\vec{v}$ PERPENDICULAR TO LOS)

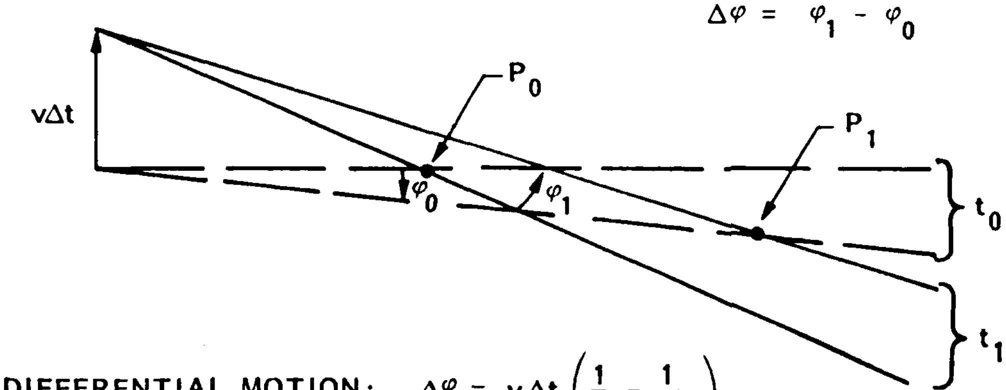


$\Delta t = t_1 - t_0$

EACH FRAME REPRESENTS A DIFFERENT PROJECTED VIEW OF THE 3-D CLOUD DISTRIBUTION

AZIMUTHAL MOTION OF P_1 BETWEEN SUCCESSIVE FRAMES:

$\Delta\varphi = \varphi_1 - \varphi_0$



DIFFERENTIAL MOTION: $\Delta\varphi = v\Delta t\left(\frac{1}{R} - \frac{1}{R_0}\right)$

RANGE (km)	$\Delta\varphi$ (SCENEL)
375	- 8.63
400	-12.1
425	-15.1
450	-17.8
475	-20.2
500	-22.4

(CUMULUS SCENE)

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SIGNAL PROCESSING SIMULATION

IMAGE SEQUENCE

1. CUMULUS SCENE WITH TARGETS
2. OPTICALLY BLURRED SCENE (5 x 5 GAUSSIAN FILTER)
3. FOCAL PLANE IMAGE (PIXEL = 5 x 5 SCENEL)
4. FIRST DIFFERENCE IMAGE

CLUTTER SUPPRESSION

	MEAN IRRADIANCE (10^{-12} W cm^{-2})	STANDARD DEVIATION (10^{-12} W cm^{-2})	SNR AS FUNCTION OF TARGET INTENSITY, J/J_o				
			0.5	1.0	2.0	5.0	10.0
FOCAL PLANE IMAGE	569	38.1	0.35	0.53	0.94	2.01	3.71
FIRST DIFFERENCE	0.031	3.06	1.37	0.85	5.77	18.4	40.7

SNR = E/σ

J_o = 955 W sr^{-1}

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DATA NEEDS FOR SCENE GENERATION PROGRAM

- RADIOMETRIC DATA FOR VALIDATION OF SYNTHETIC SCENES
  - HIGH SPATIAL RESOLUTION
  - HIGH RADIOMETRIC RESOLUTION
  - PROPER VIEWING GEOMETRY
  - VARIETY OF CLOUD TYPES
- CLOUD DATA FOR IMPROVING MODEL
  - VALUES OF CLOUD SHAPE PARAMETERS
  - MODEL OF FINE SCALE STRUCTURE OF CLOUD EDGES
  - SMALL-SCALE DISTRIBUTION OF WATER/ICE CONTENT INSIDE CLOUDS

IR RADIATIVE PROPERTIES OF CIRRUS AND CUMULUS CLOUDS AND IRST APPLICATION

G. Gal
T. P. Winarske
Lockheed Palo Alto Research Laboratory

IR RADIATIVE PROPERTIES OF CIRRUS AND CUMULUS CLOUDS AND IRST APPLICATION

G. GAL
T. P. WINARSKE

TRI-SERVICE CLOUD MODELING WORKSHOP
NAVAL SURFACE WEAPON CENTER, WHITE OAK, MD
JUNE 26 - 28, 1984

LOCKHEED PALO ALTO RESEARCH LABORATORY
3251 HANOVER ST.
PALO ALTO, CA 94304

IR Radiative Properties of Cirrus and
Cumulus Clouds and IRST System Application

G. Gal and T. Winarske
Lockheed Palo Alto Research Laboratory

A serious problem in the IR radiometric measurements from an airbourne platform is the interpretation of the target signal through the atmosphere and the interference of clouds particularly the globally distributed cirrus layers or local cumulus clouds. For various system applications such as HI-CAMP, IRST deterministic cloud radiance distribution must be generated. Our goal was to assemble a computer model to calculate cloud spectral radiance and atmospheric transmittance based on realistic cloud physical parameters and various irradiance models such as: direct emission including multiple scattering effects, scattering of diffuse earthshine, upwelling and downwelling airshine, scattered sun and solar radiance.

Furthermore a first order attempt has been made to obtain an estimate of the effects of a nearby cloud (mutual coupling) and cloud edge radiance values. Evaluation of these contributions require the solution of the radiative transfer equation for a coupled sky-cloud-solar-earth system for the particular geometric configuration. Neither physical input nor the computational methodology is currently available. Our approach was to break down the problem to the solution of well defined model problem to obtain cloud internal radiation field for given cloud model parameters and obtain some quantitative estimate of the relative importance of the various irradiance contributions.

A plane parallel atmosphere with horizontal extent is treated as being made up of stratified layers. The cloud layer is located at an arbitrary altitude divided into small sublayers. Clear air extent below and above the cloud. The cloud layer consists of clear atmospheric molecules and arbitrary droplet size distribution described by modified gamma distribution or similar continuous function. Altitude dependent meterological and microphysical are input data. These are air pressure, temperature dew temperature, droplet concentration, etc. Radiative transport equation for a monochromatic radiation through thus inhomogeneous scattering and absorbing layers which assumed to be in local thermodynamic equilibrium is

$$\mu \frac{dI_\lambda(\tau;\Theta,\phi)}{d\tau} = I_\lambda(\tau;\Theta,\phi) - \omega_\lambda(\tau)J_\lambda(\tau;\Theta,\phi)$$

Where I_λ and J_λ is the spectral intensity and source term respectively; $\omega_\lambda(\tau)$ single scattering albedo; μ is the cosine of the zenith angle Θ; ϕ is the azimuth angle. The optical depth τ is directly obtained from rigorous Mie theory of scattering from the assumed cloud particle size distribution. Similarly, the cloud averaged scattering phase function is obtained as a sum of the Rayleigh (molecular) and Mie (particulate) components. Utilizing the Lengendre and Fourier series expansion of the phase function the solution of the radiative transfer equation is obtained by a numerical method outlined by Dave-Gazdag with modification introduced by Low.

For our Cloud Clutter Model Development program our interest has been focused in the $8 \leq \lambda$ (μm) ≤ 12 spectral band. Spectral up/down-welling radiance values are obtained as a function of Nadir angle for an Azimuthal symmetric case (sun has been omitted for this particular spectral region) for a cirrus, cumulus and cumulus edge with or without atmospheric layer above or below the cloud layer.

This model solution is the point of departure for constructing engineering models for different system applications, such as the shallow angle viewing IRST study. Particular details of the cloud scenes, both physical and morphological, are taken into account by this simplified engineering model. Estimates have been obtained for radiance values for multilayer clouds, cumulus edge effects, as well as for the different source irradiance contribution to the total radiance values. This is particularly important for very shallow viewing angles where the LOS does not intercept the earth surface.

For a general data analysis and background study this computer model may be applicable upon completition of the numerical solution for other spectral regions. It would be especially important to compare the prediction of cumulus edge radiance values with recently obtained experimental data.

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IR RADIATIVE PROPERTIES OF CIRRUS AND CUMULUS CLOUDS AND IRST APPLICATION

G. GAL

T. P. WINARSKE

LOCKHEED PALO ALTO RESEARCH LABORATORY

TRI-SERVICE CLOUD MODELING WORKSHOP

NAVAL SURFACE WEAPON CENTER, WHITE OAK, MD

JUNE 26 - 28, 1984

RADIANCE MODELING

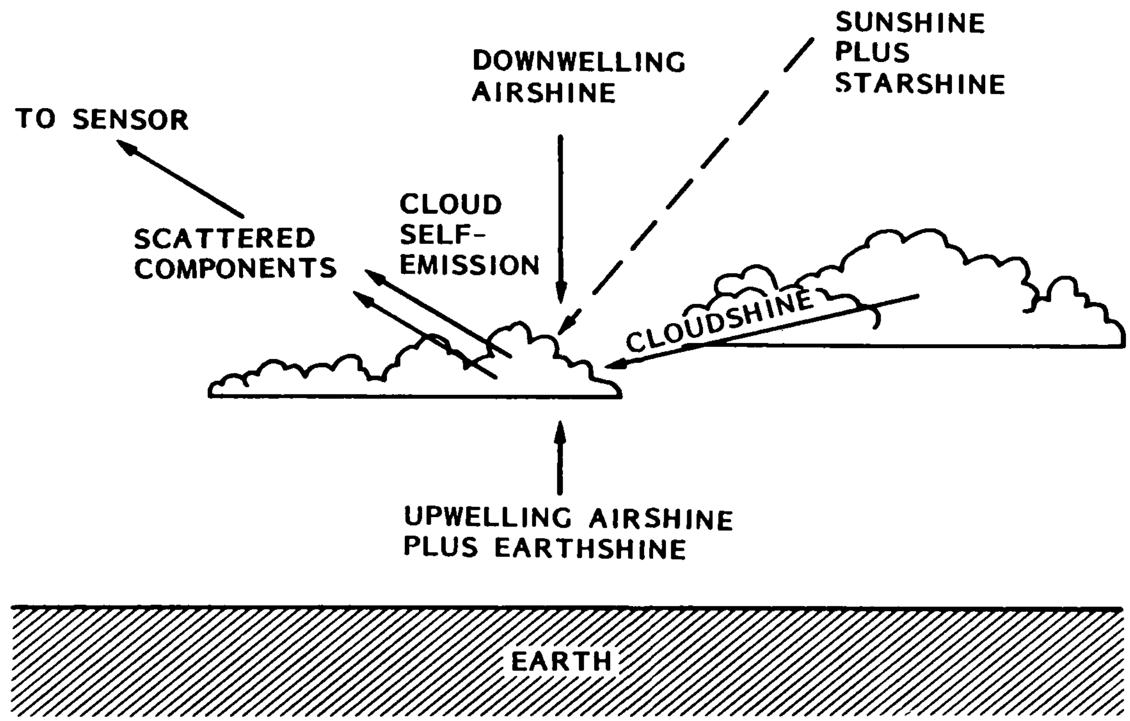
1. OBJECTIVE: PROVIDE INFRARED RADIANCE MODELS FOR A REALISTIC ATMOSPHERE WITH OPTICALLY THIN/THICK CLOUD LAYERS FOR VARIOUS SPECTRAL REGIONS

2. APPROACH: MEAN LAYER APPROXIMATION – SINGLE AND MULTIPLE SCATTERING MIE CODES

3. EVALUATE THE FOLLOWING EFFECTS ON SCENE GENERATION ($8 \leq \lambda\ [\mu m] \leq 12$):
   - SPECTRAL AND ANGULAR DEPENDENCE MODEL FOR UPWARD RADIANCE
   - EARTHSHINE IRRADIANCE ON CLOUD AND PATH
   - AIRSHINE IRRADIANCE BELOW AND ABOVE THE CLOUD LAYER
   - MULTIPLE SCATTERING EFFECT (DIRECT AND DIFFUSE RADIANCE)
   - CLOUD MODELS
   - MULTILAYER CLOUD MODEL
   - EDGE EFFECTS
   - SHALLOW LOS EFFECTS ON TRANSMISSIVITY, EMISSIVITY, AND REFLECTIVITY

4. ENGINEERING MODEL: DETERMINISTIC, PHYSICS-BASED ALGORITHMS FOR GENERATING SYNTHETIC CLOUD SCENES

SOURCES OF CLOUD RADIANCE



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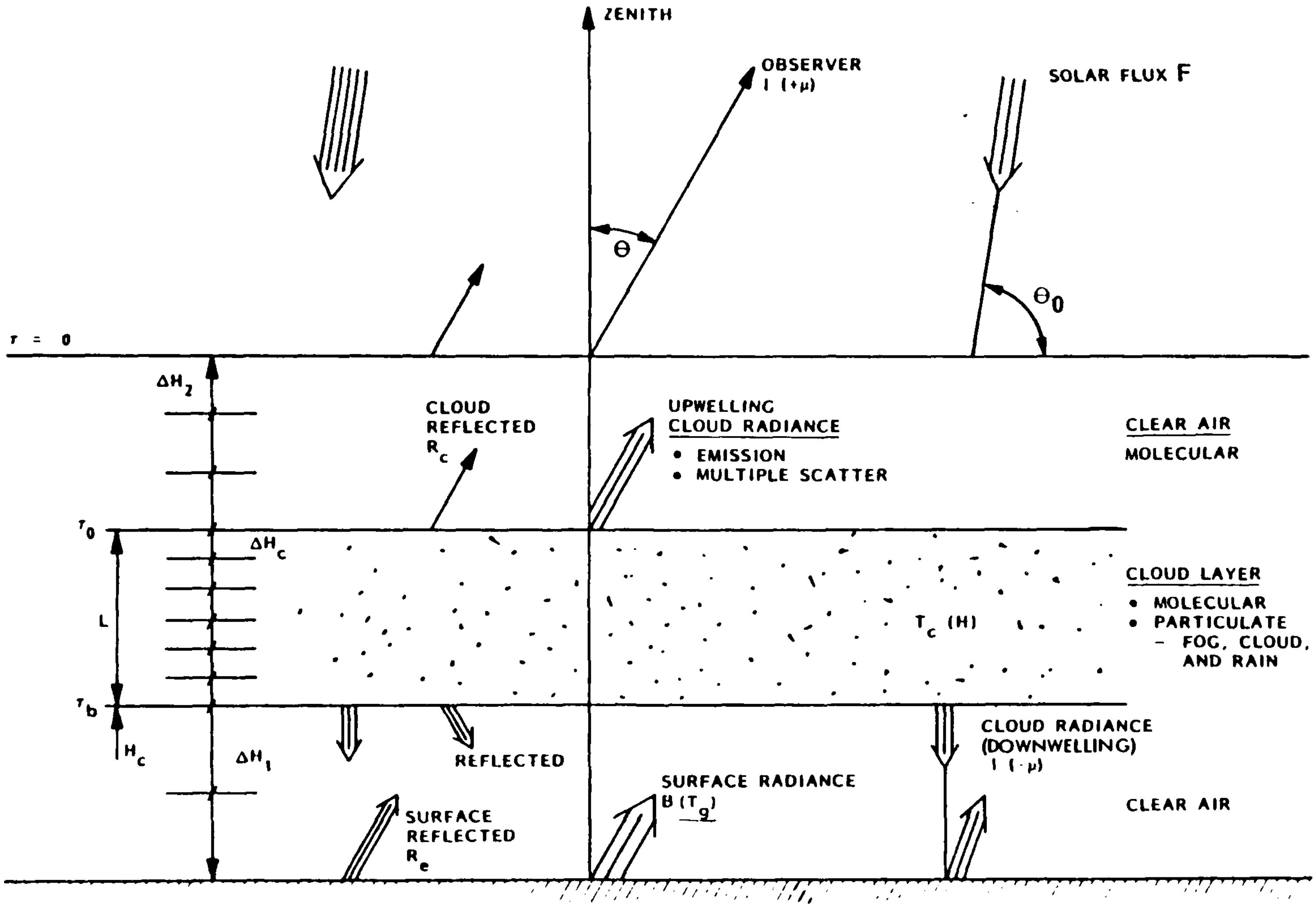
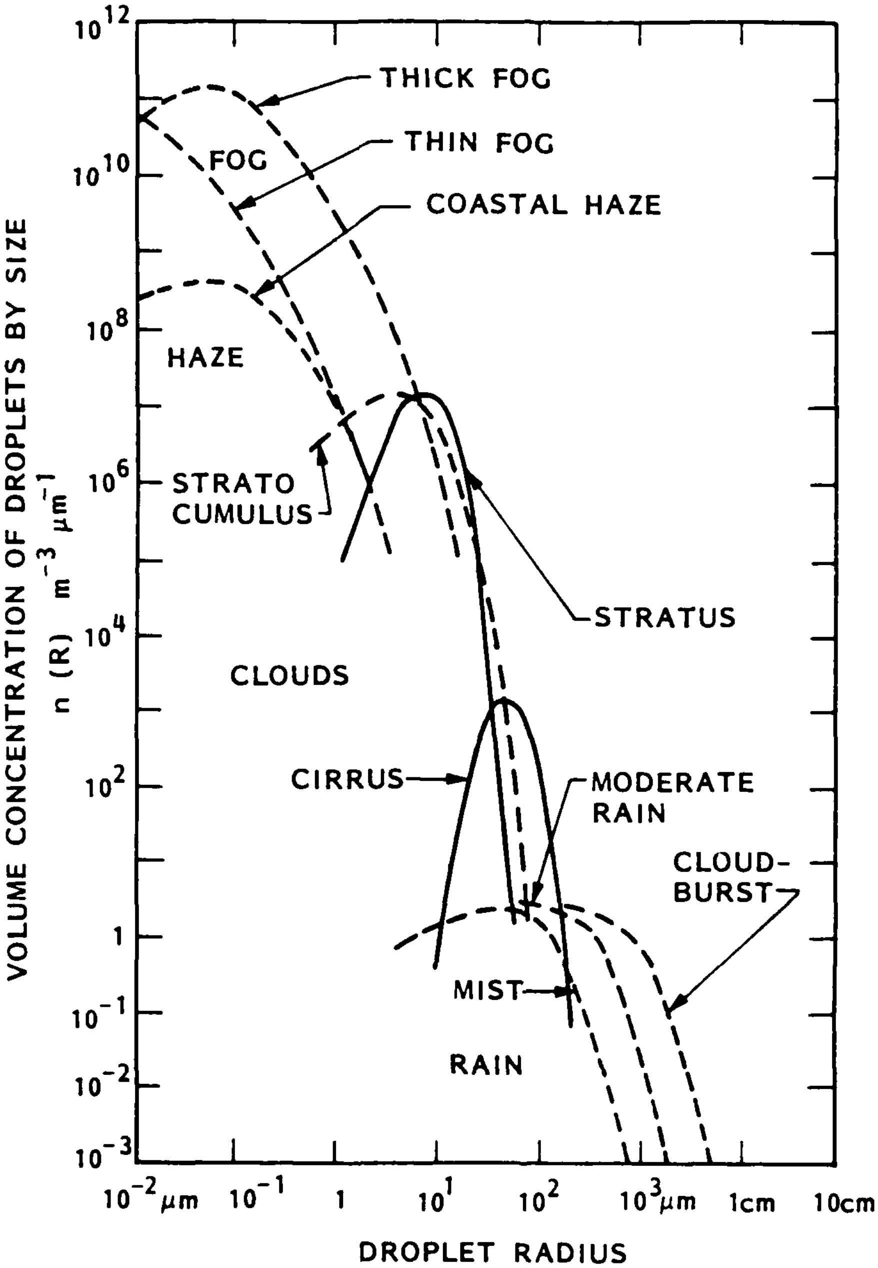
SOURCES OF RADIANCE IN THE ATMOSPHERE



WATER AEROSOL DISTRIBUTION FUNCTIONS



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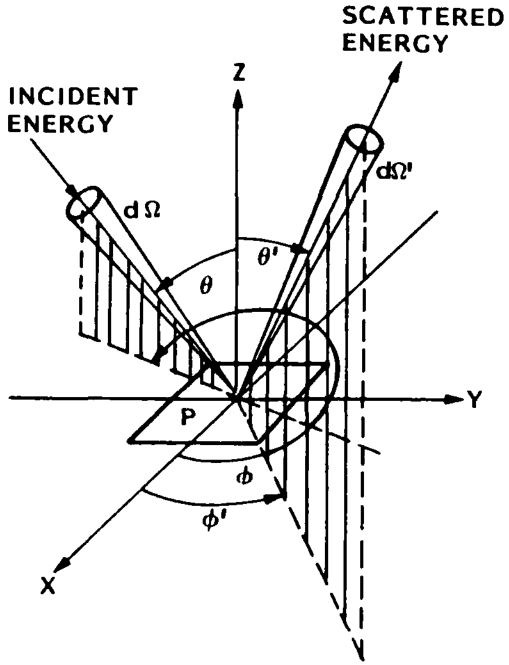
RADIATIVE TRANSFER EQUATION



$$\mu \frac{dI(\tau;\mu,\varphi)}{d\tau} = I(\tau;\mu,\varphi) - \omega(\tau)\, J(\tau;\mu,\varphi)$$

THREE COMPONENTS

$$I = I_{SOLAR} + I_{EARTH} + I_{CLOUD}$$

$$J = J_{SOLAR} + J_{EARTH} + J_{CLOUD}$$

SCATTERING ANGLE

$$\cos\psi = \mu\mu' + (1-\mu^2)^{1/2}(1-\mu'^2)^{1/2}\cos(\varphi' - \varphi)$$

OPTICAL DEPTH

$$\tau = \tau^{(R)} + \tau^{(M)} = \left[\frac{P}{P_o}\tau^{S,R} + \tau_V + \tau_L\right] + \frac{N(h)}{N_o}\beta ext$$

SINGLE SCATTERING ALBEDO

$$\omega(\tau) = \frac{\delta\tau^{(S,M)} + \delta\tau^{(S,R)}}{\delta\tau^{(M)} + \delta\tau^{(R)}}$$

TURBIDITY

$$T(\tau) = \frac{\delta\tau^{(S,M)}}{\delta\tau^{(S,M)} + \delta\tau^{(S,R)}}$$

SCATTERING FUNCTION

$$P(\tau;\mu,\varphi;\mu',\varphi') = T(\tau)\, M(\mu,\varphi;\mu',\varphi') + [1 - T(\tau)]\, R(\mu,\varphi;\mu',\varphi')$$

RADIATION TYPE	SOURCE FUNCTION	BOUNDARY FUNCTION
SOLAR RADIATION J_s	$J_s(\tau;\mu,\phi) = \frac{1}{4} F e^{-\tau/\mu_0} P(\tau;\mu\mu_o', \phi\phi_o') + \frac{1}{4\pi}\int_0^{2\pi}\int_{-1}^{1} [P(\tau;\mu\mu',\phi\phi')\, I_s(\tau;\mu',\phi')]\, d\mu'\, d\phi'$	$I_s(0;-\mu,\phi) = 0$ $I_s(\tau_b;+\mu,\phi) = 0$
GROUND RADIATION J_g	$J_g(\tau;\mu) = \frac{\omega_o(\tau)}{2}\int_{-1}^{+1} P^{(1)}(\mu\mu')\, I_g(\tau;\mu')\, d\mu'$	$I_g(0;-\mu) = 0$ $I_g(\tau_b;+\mu) = B(T_g)$
CLOUD EMISSION J_c	$J_c(\tau;\mu,\phi) = (1-\omega_o) B[T_c(\tau)] + \frac{1}{2}\int_{-1}^{1} P^{(1)}(\tau;\mu\mu')\, I_c(\tau;\mu')\, d\mu'$	$I_c(0;-\mu) = 0$ $I_c(\tau_b;+\mu) = 0$

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FOURIER EXPANSION

REQUIRED FOR THE SOLUTION OF I_{SOLAR} COMPONENTS IF AZIMUTHAL ϕ DEPENDENCY IS NOT NEGLIGIBLE; $\mu_o \neq 0$

SCATTERING FUNCTION

$$P(\tau;\mu,\varphi;\mu',\varphi') = \sum_{n=1}^{N(\mu,\mu')} P^{(n)}(\tau;\mu,\mu')\cos(n-1)(\varphi'-\varphi) ,$$

WHERE

$$P^{(n)}(\tau;\mu,\mu') = T(\tau)M^{(n)}(\mu,\mu') + [1 - T(\tau)]\, R^{(n)}(\mu,\mu') ,$$

INTENSITY

$$I_s(\tau;\mu,\varphi) = \sum_{n=1}^{N(\mu_o)} I_s^{(n)}(\tau;\mu)\cos(n-1)(\varphi_o-\varphi) ,$$

SOURCE FUNCTION

$$J_s(\tau;\mu,\varphi) = \sum_{n=1}^{N(\mu_o)} J_s^{(n)}(\tau;\mu)\cos(n-1)(\varphi_o-\varphi) .$$

$$J_s^{(n)}(\tau;\mu) = \frac{1}{4} F e^{-\tau/\mu_o} P^{(n)}(\tau;\mu,-\mu_o)$$

$$+ \frac{(1+\delta_{1n})}{4} \int_{-1}^{+1} P^{(n)}(\tau;\mu,\mu') I_s^{(n)}(\tau;\mu') d\mu'$$

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GAUSS – SEIDEL ITERATIVE SOLUTION

TRANSFER EQUATION SYSTEM

$$\mu \sum_{n=1}^{N(\mu_o)} \frac{dI_j^{(n)}(\tau;\mu)}{d} \cos(n-1)(\varphi_o - \varphi) = \sum_{n=1}^{N(\mu_o)} I_j^{(n)}(\tau;\mu)\cos(n-1)(\varphi_o - \varphi) - \omega(\tau) \sum_{n=1}^{N(\mu_o)} j_j^{(n)}(\tau;\mu)\cos(n-1)(\varphi_o - \varphi)$$

BOUNDARY CONDITION

SOLAR RADIATION	EARTH RADIATION	CLOUD EMISSION
$j=1$	$j=2$	$j=3$
$1 < n < N$	$n=1$	$n=1$
$I_s^{(n)}(0; -\mu, \varphi) = 0$	$I_g^{(1)}(0; -\mu) = 0$	$I_c^{(1)}(0; -\mu) = 0$
$I_s^{(n)}(\tau_b; \mu, \varphi) = 0$	$I_g^{(1)}(\tau_b; +\mu) = B(T_g)$	$I_c^{(1)}(\tau_b; \mu) = 0$

ITERATIVE SOLUTION IS OBTAINED FOR EACH FOURIER HARMONICS "n" IN EVERY ATMOSPHERIC LAYER (L) WITH THE DIRECT AND SELF EMISSION TERMS AS INITIAL VALUE

$$I_{m+1}^{(n)}(\tau_{L+1}; -\mu) / I_m^{(n)}(\tau_{L+1}; -\mu) \le \epsilon$$

NOTE: REFLECTED EARTH SURFACE RADIATION IS NEGLECTED

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CLOUD OPTICAL PROPERTIES

EMISSIVITY

$$\epsilon_\lambda(\mu) = \frac{I_\lambda^C(\tau;\mu)}{B_\lambda(\tilde{T}_c)}$$

TRANSMISSIVITY

$$T(\mu,\phi) = \frac{I_\lambda^S(\tau_b;\ \mu,\phi)}{H_\lambda^S(\tau = 0)}$$

$$T(\mu) = \frac{I_\lambda^G(\tau=0;\mu)}{B_\lambda(T_G)}$$

REFLECTIVITY

$$R(\mu\phi) = \frac{I_\lambda^S(\tau = 0, \mu\phi)}{H_\lambda^S(\tau=0)}$$

WHERE

$\tilde{T}_C$ = CLOUD BLACKBODY REFERENCE TEMPERATURE

T_G = GROUND SURFACE TEMPERATURE

B_λ = PLANCK FUNCTION

H_λ^S = SOLAR IRRADIANCE

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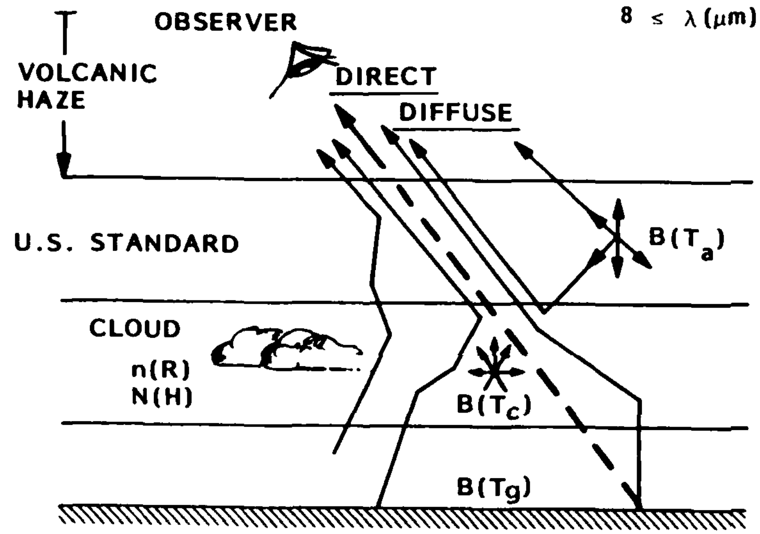
IRST APPLICATION: BASIC MODEL



SPECTRAL REGION
$8 \leq \lambda (\mu m) \leq 12$

- PLANE PARALLEL ATMOSPHERE
- MULTIPLE SCATTER SOLUTION $0 \leq H \leq 10$ km
  LOWTRAN EXTENSION $10 < H \leq H_{obs}$
- ANGULAR EFFECTS
  $0 \leq \theta \leq 90$ deg
- GAMMA DISTRIBUION
  $N(r) = a\ r^{\alpha} \exp(-br)$

  $N = \frac{W}{\bar{C}}$ #/cm^3

- OPTICAL PROPERTIES
- CLEAR ATMOSPHERE [LOWTRAN 5]
- CIRRUS [LIOU'S EXPERIMENTS]
- CUMULUS [PLATT'S EXPERIMENTS]

DUE TO EARTH CURVATURE, DIRECT EARTH RADIANCE MAY BE OMITTED FOR SCENARIO I AND II MODELING

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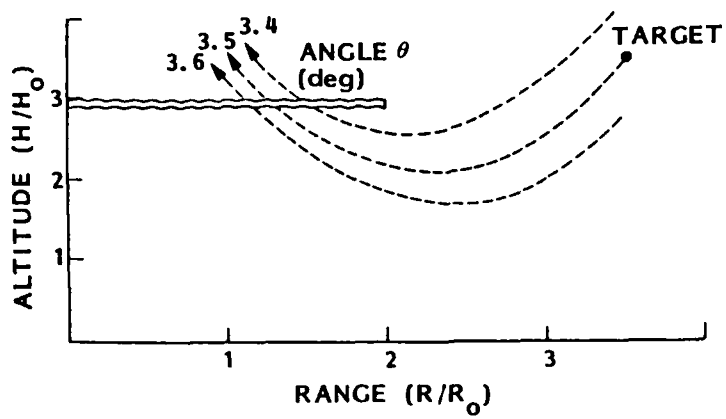
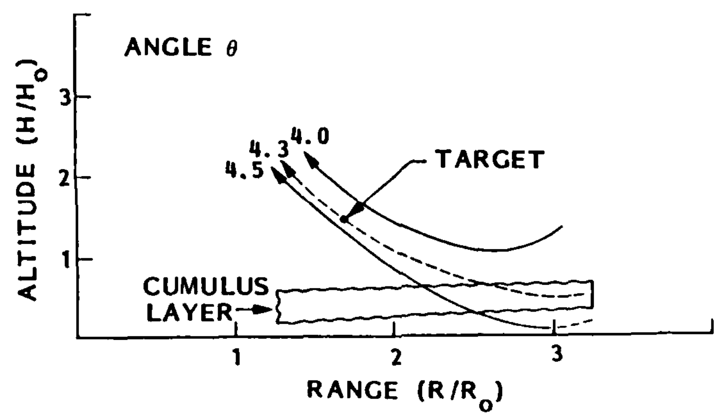
RADIANCE MODELING

SCENARIO I: THIN HIGH CIRRUS



SCENARIO II: CUMULUS LAYER



CLOUD PARAMETERS

$N(r) = 2.04\ 10^{-12}\ r^6\ e^{-0.12\ r}$

$10 \le r(\mu m) \le 200$

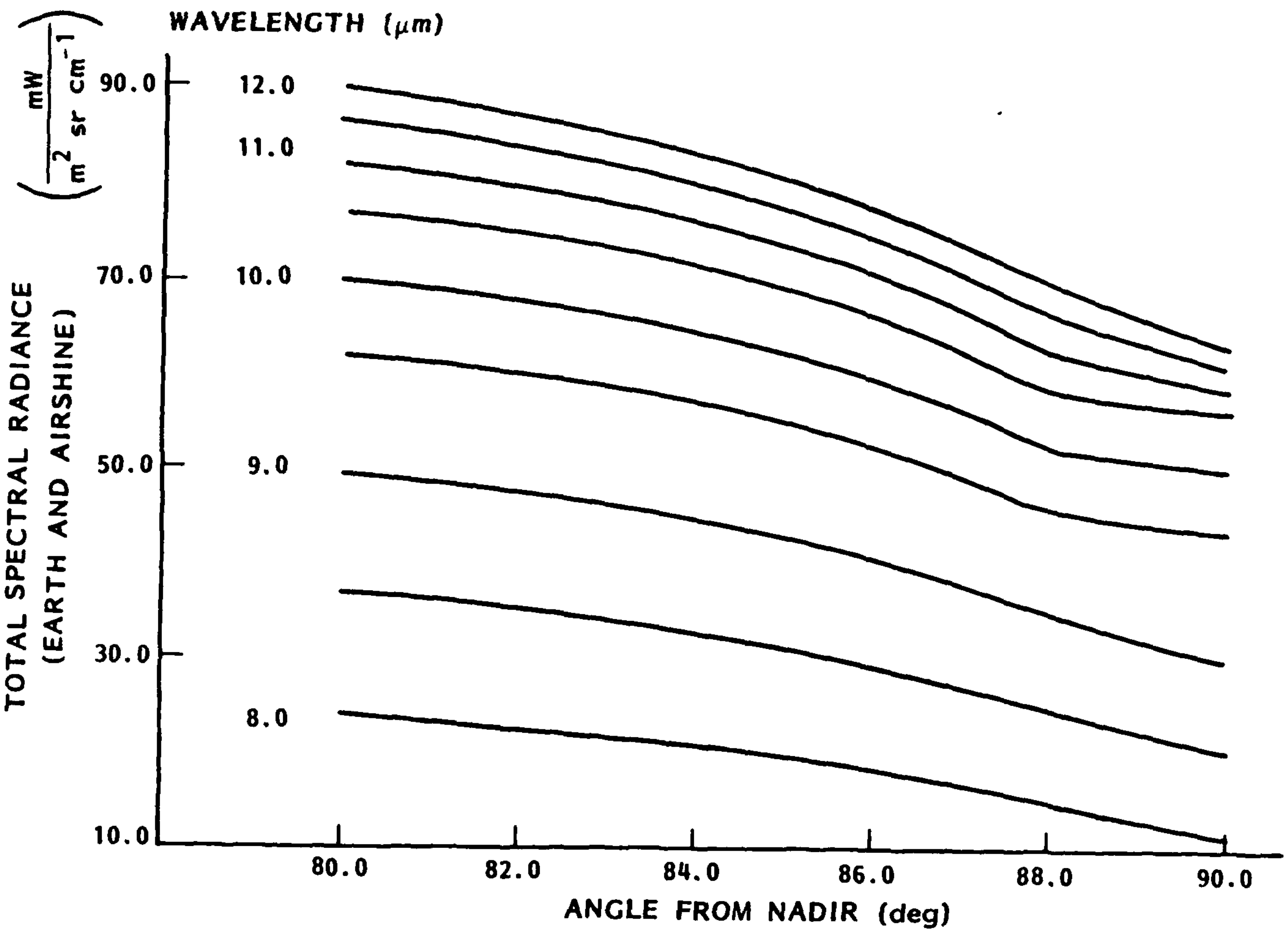
$w = 0.005\ g/m^3$

$N(r) = 8.54\ r^4\ e^{-r}$

$0.1 \le r(\mu m) \le 40$

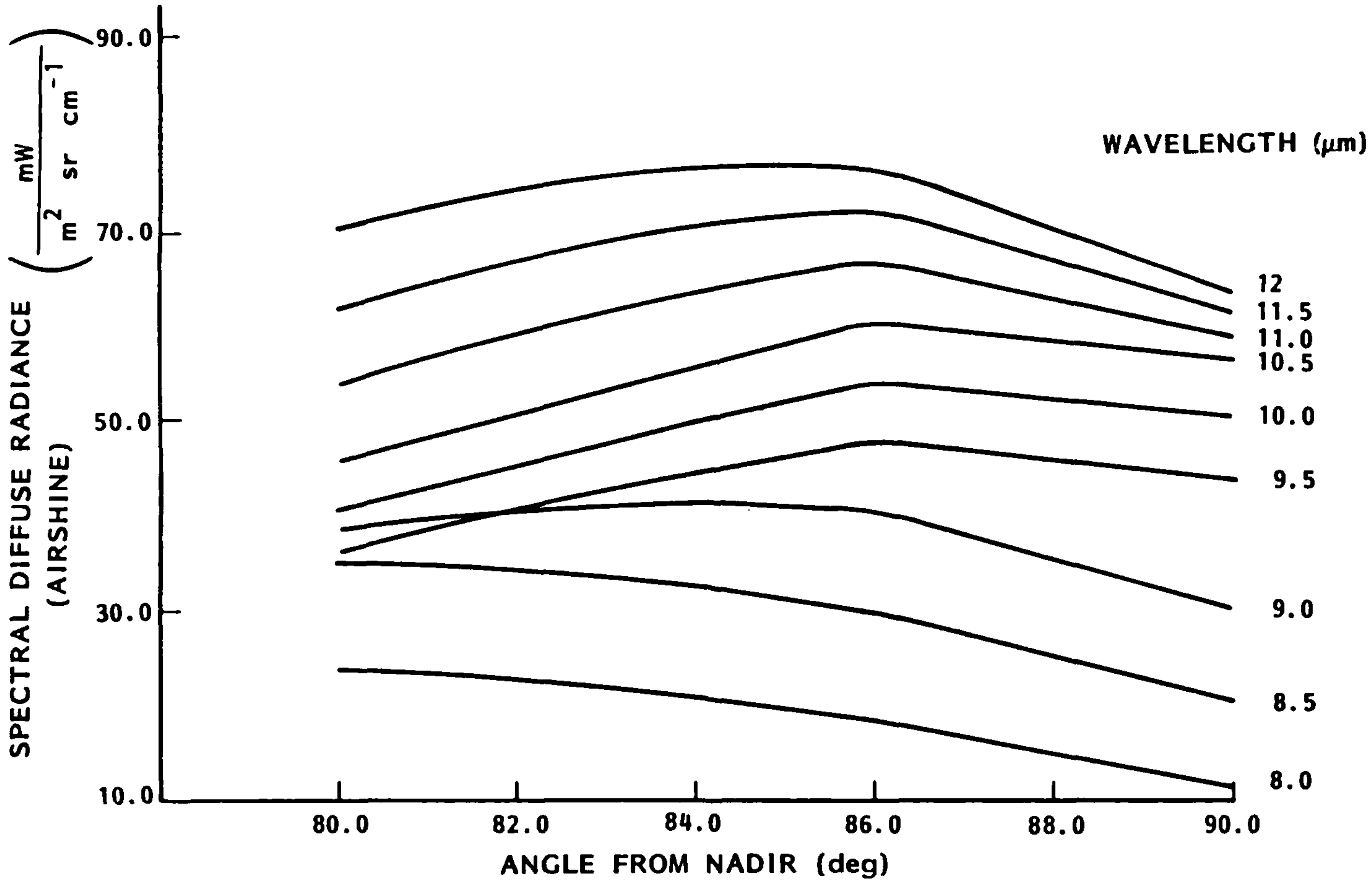
$w = 0.18\ g/m^3$

SPECTRAL RADIANCE DUE TO ATMOSPHERE PLUS EARTH



![Lockheed]

SPECTRAL RADIANCE AT H = 10 km
DUE TO ATMOSPHERE ONLY



OPTICAL DEPTH OF A HOMOGENEOUS CLOUD LAYER (U.S. STANDARD ATMOSPHERE)

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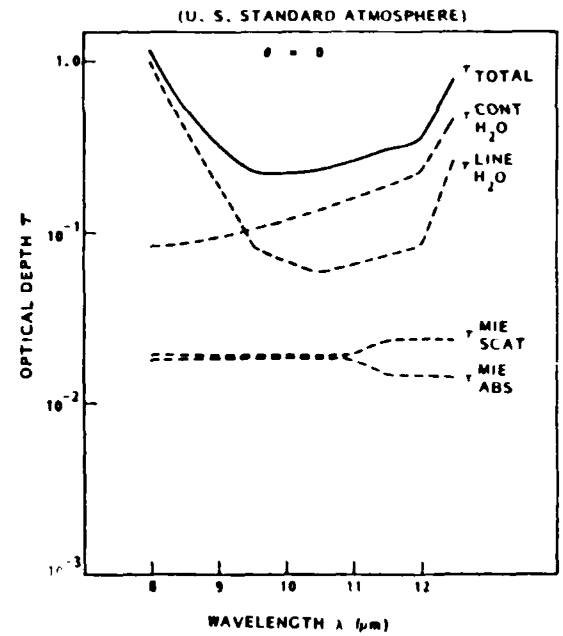
CIRRUS LAYER

ΔH = 300 m

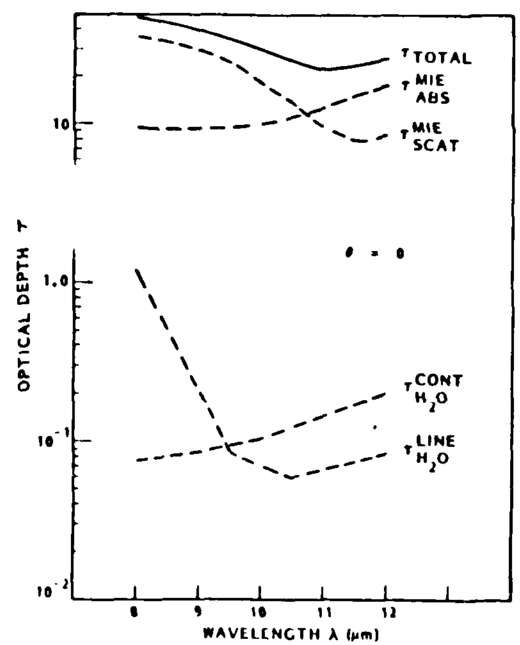
H = 9000 m



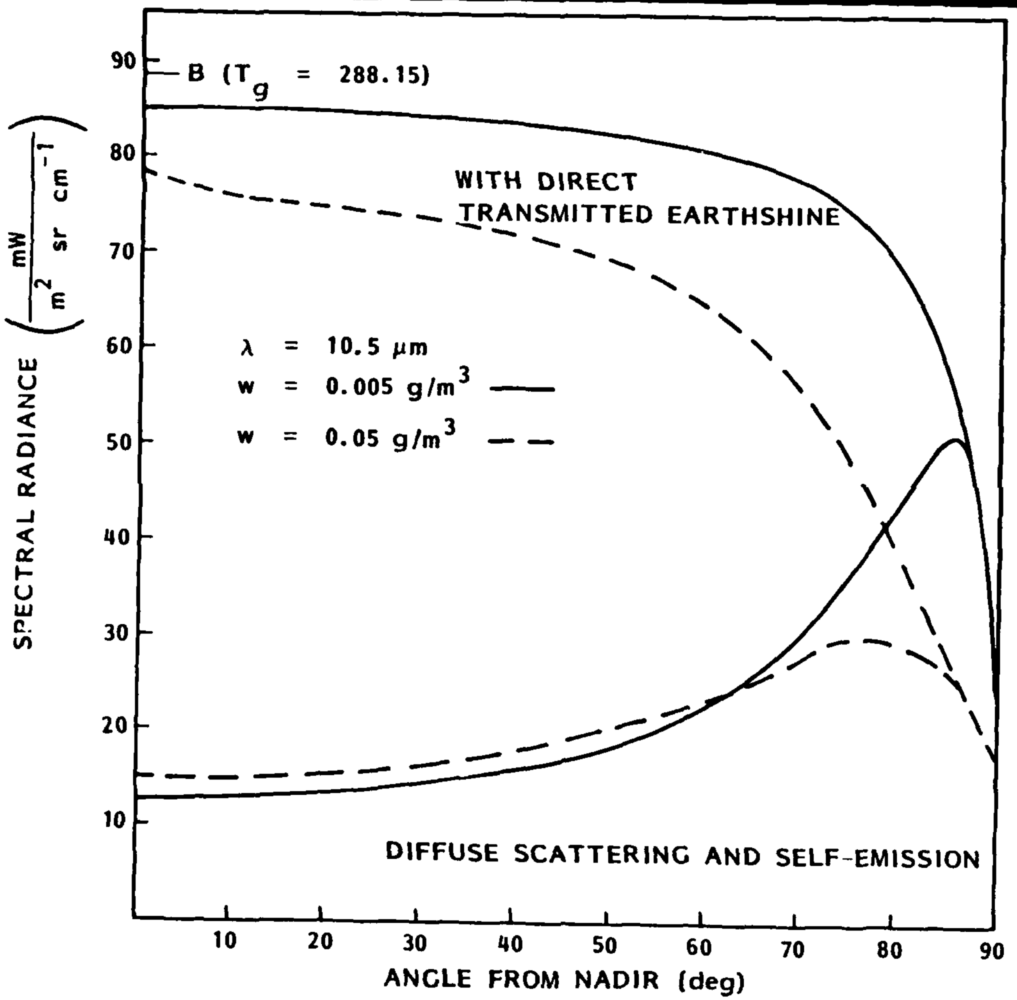
STRATOCUMULUS LAYER

ΔH = 900 m

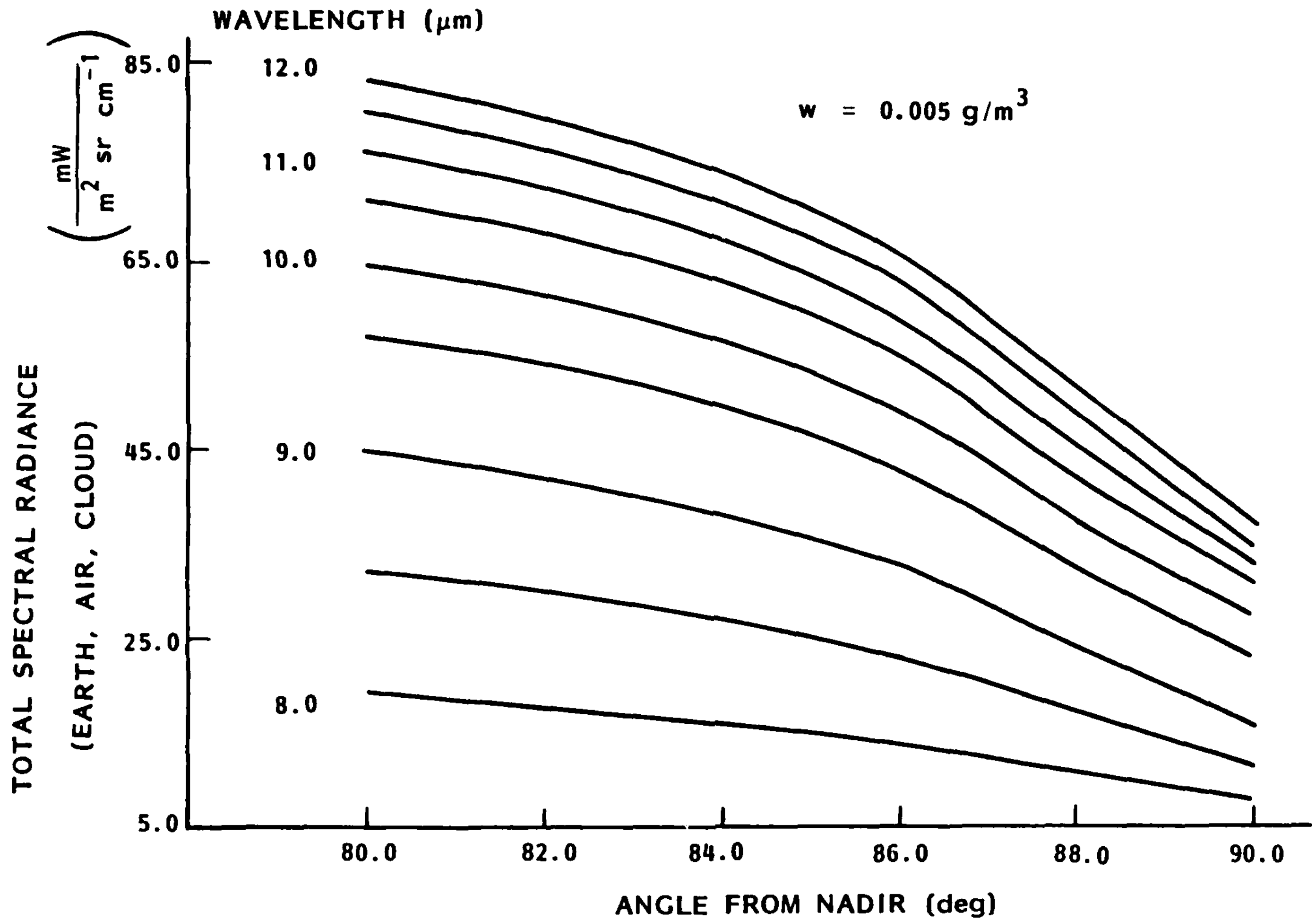
H = 1000 m



SPECTRAL RADIANCE AT H = 20 km FOR CIRRUS LAYER



SPECTRAL RADIANCE AT H = 10 km FOR CIRRUS LAYER



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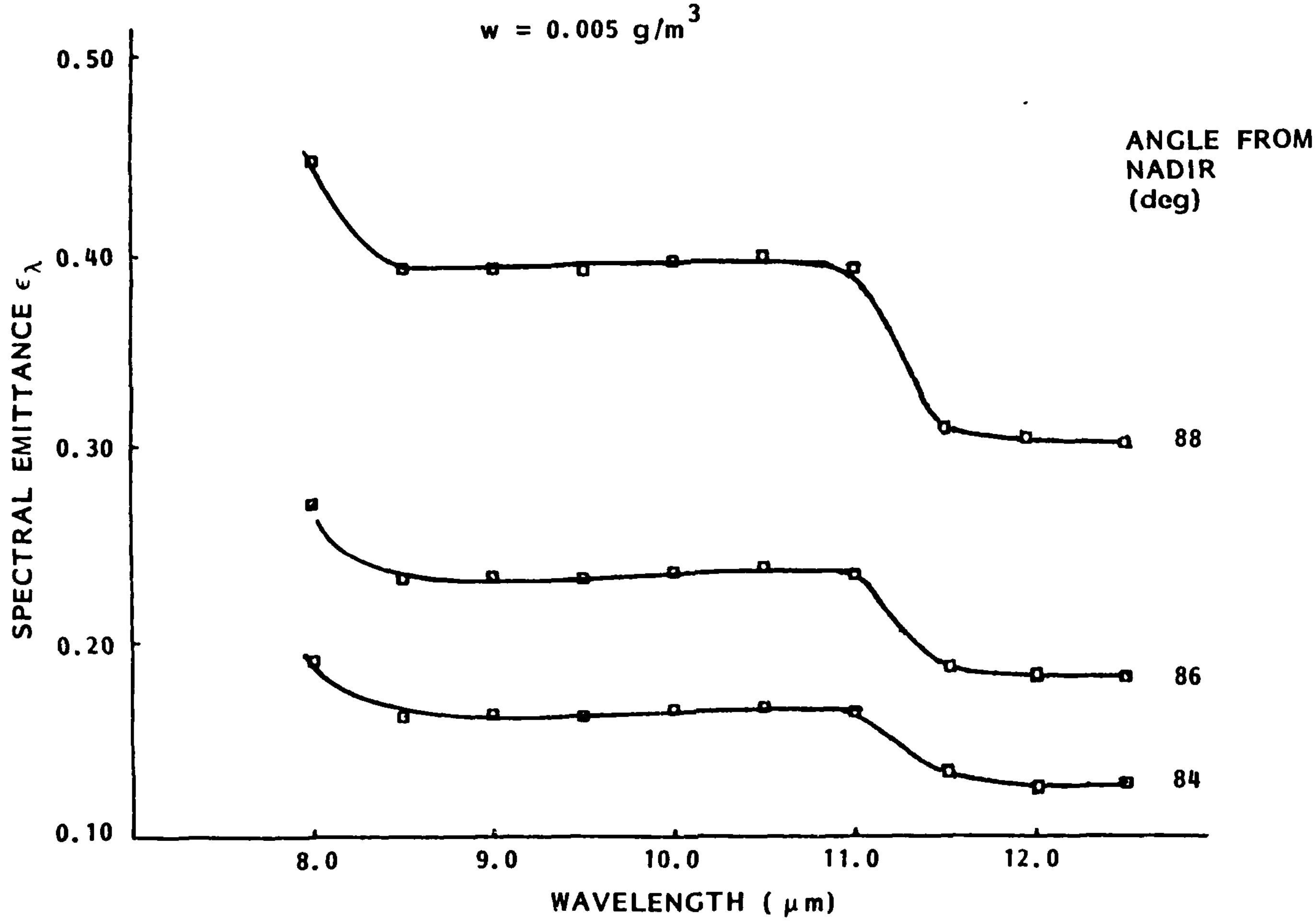
SPECTRAL EMITTANCE OF A 350 m CIRRUS LAYER



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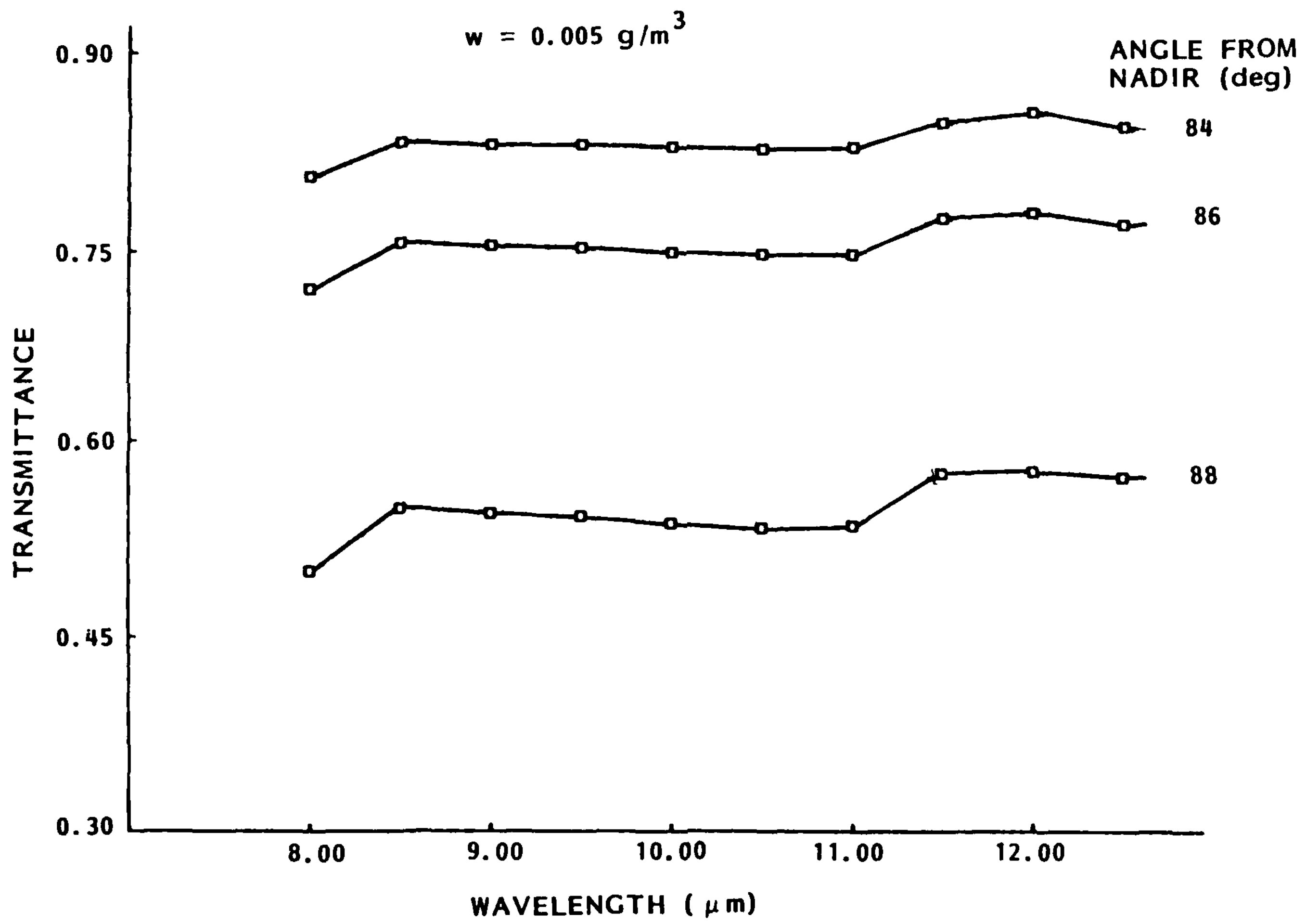
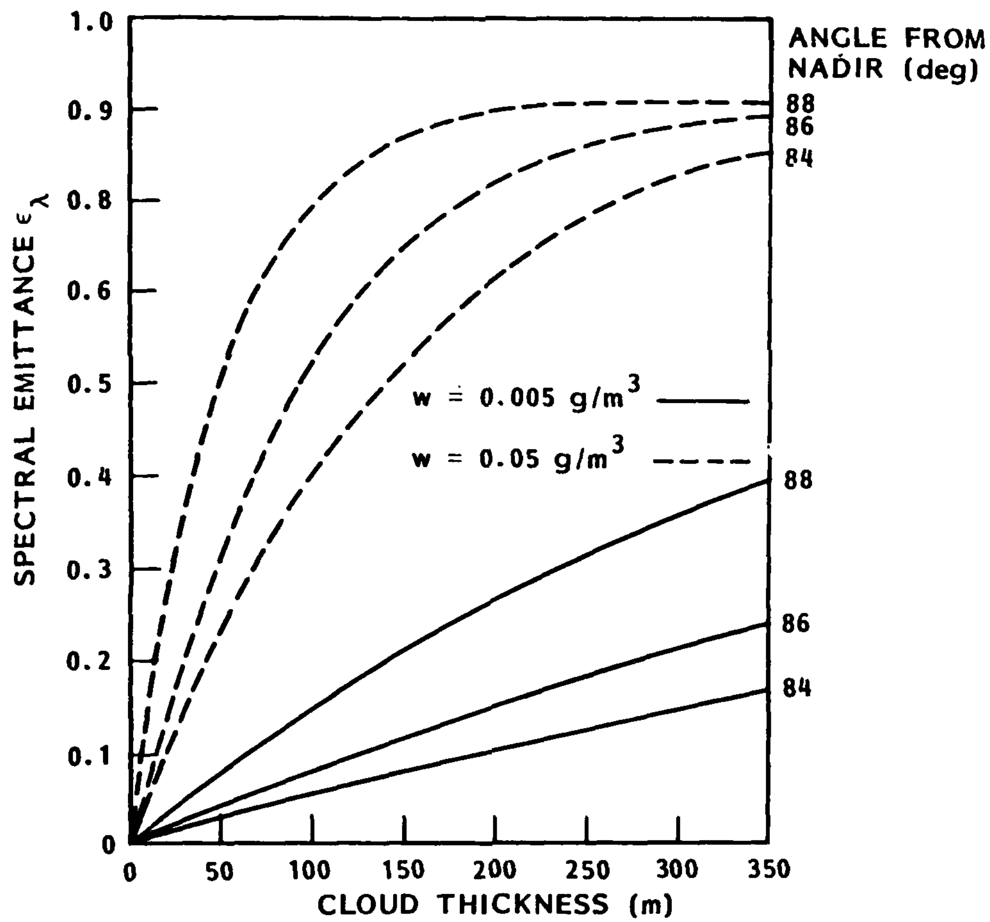
SPECTRAL TRANSMITTANCE OF A 350 m CIRRUS LAYER

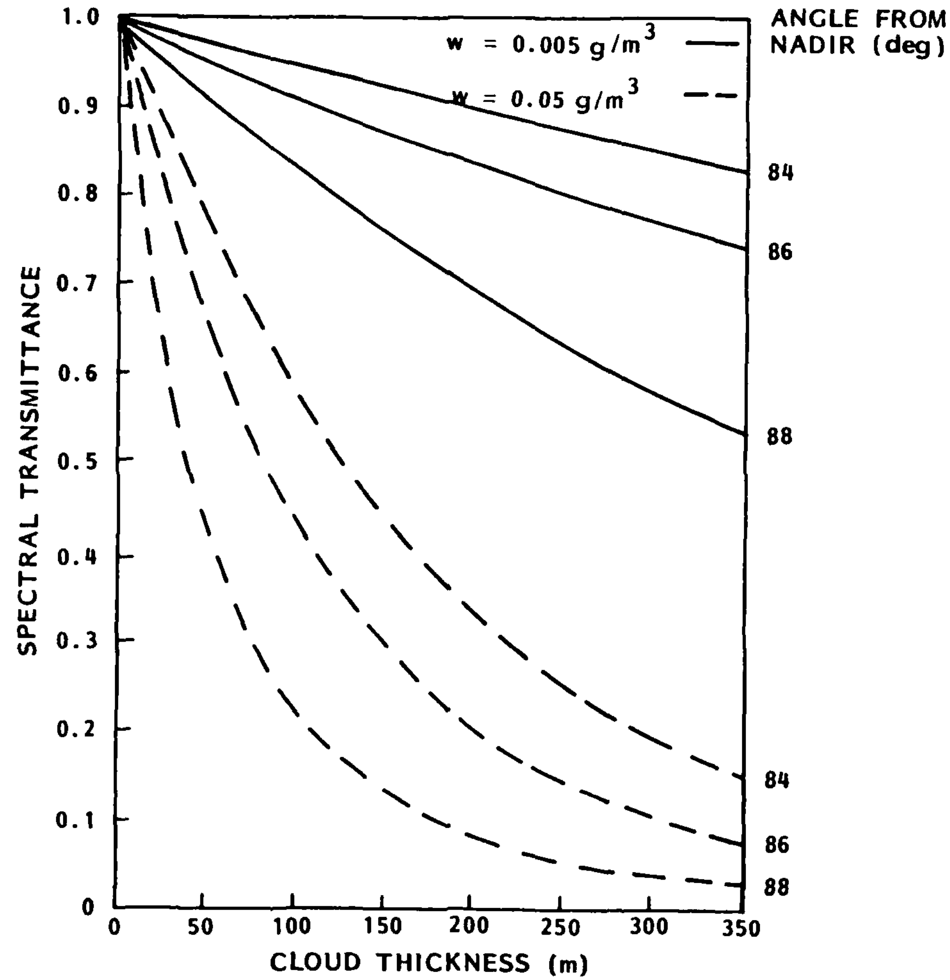


CIRRUS LAYER EMISSIVITY AT λ = 10.5 μm AS A FUNCTION OF CLOUD DEPTH

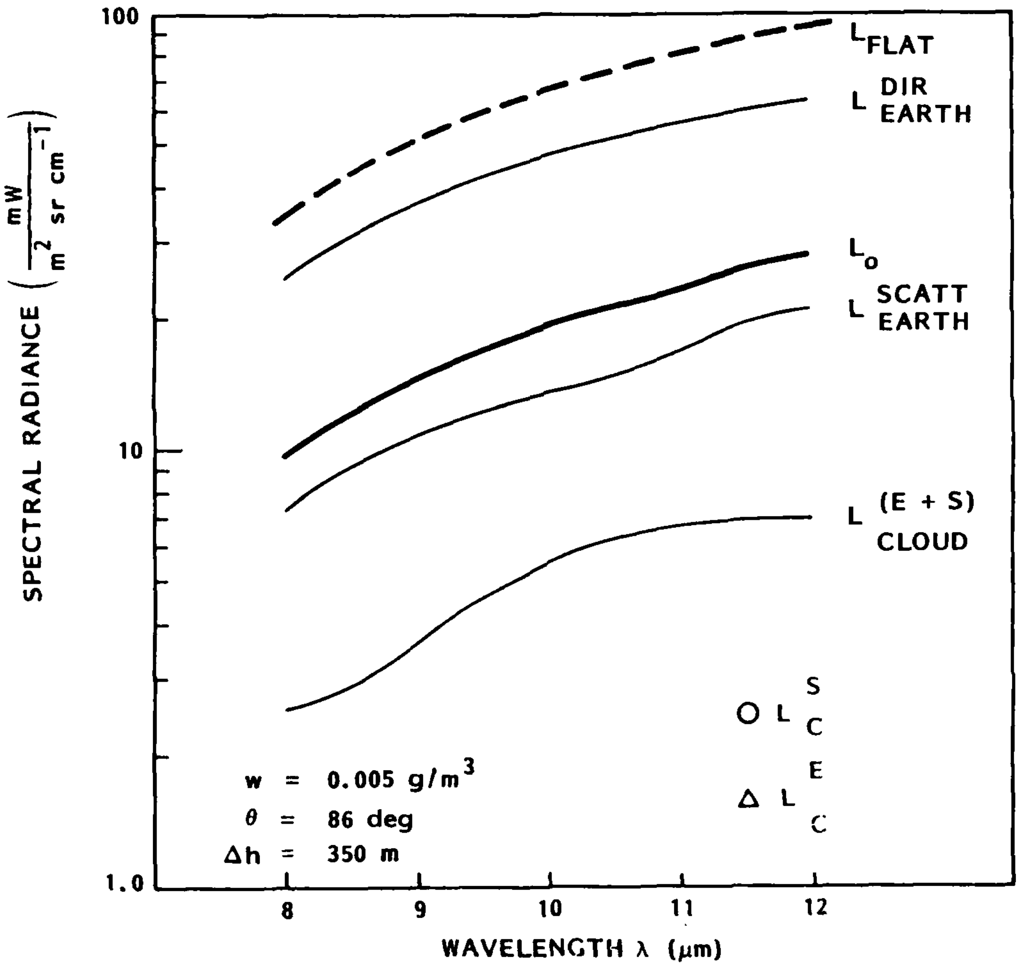


Lockheed

CIRRUS LAYER TRANSMITTANCE AT $\lambda = 10.5\ \mu m$

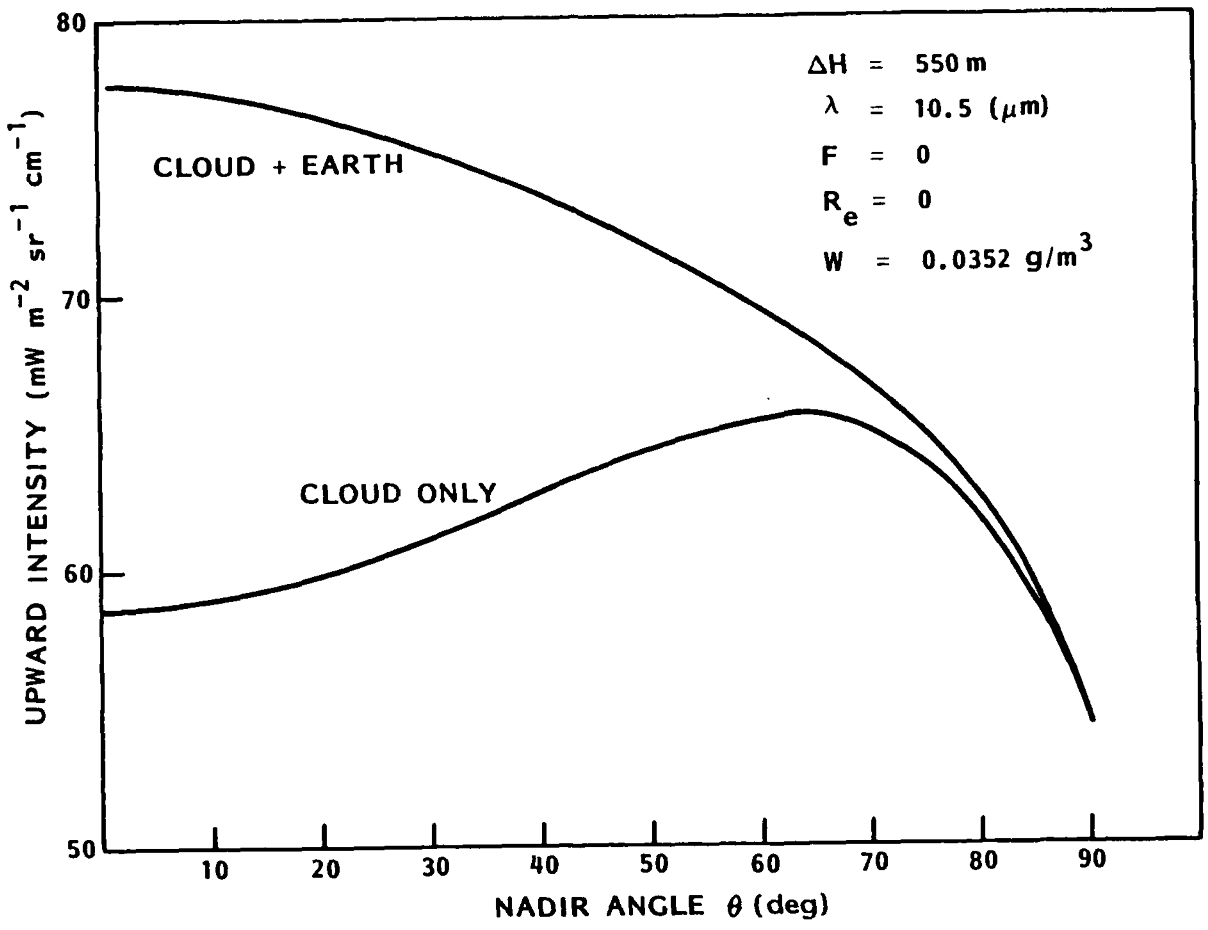


SPECTRAL RADIANCE ABOVE ISOLATED CIRRUS LAYER

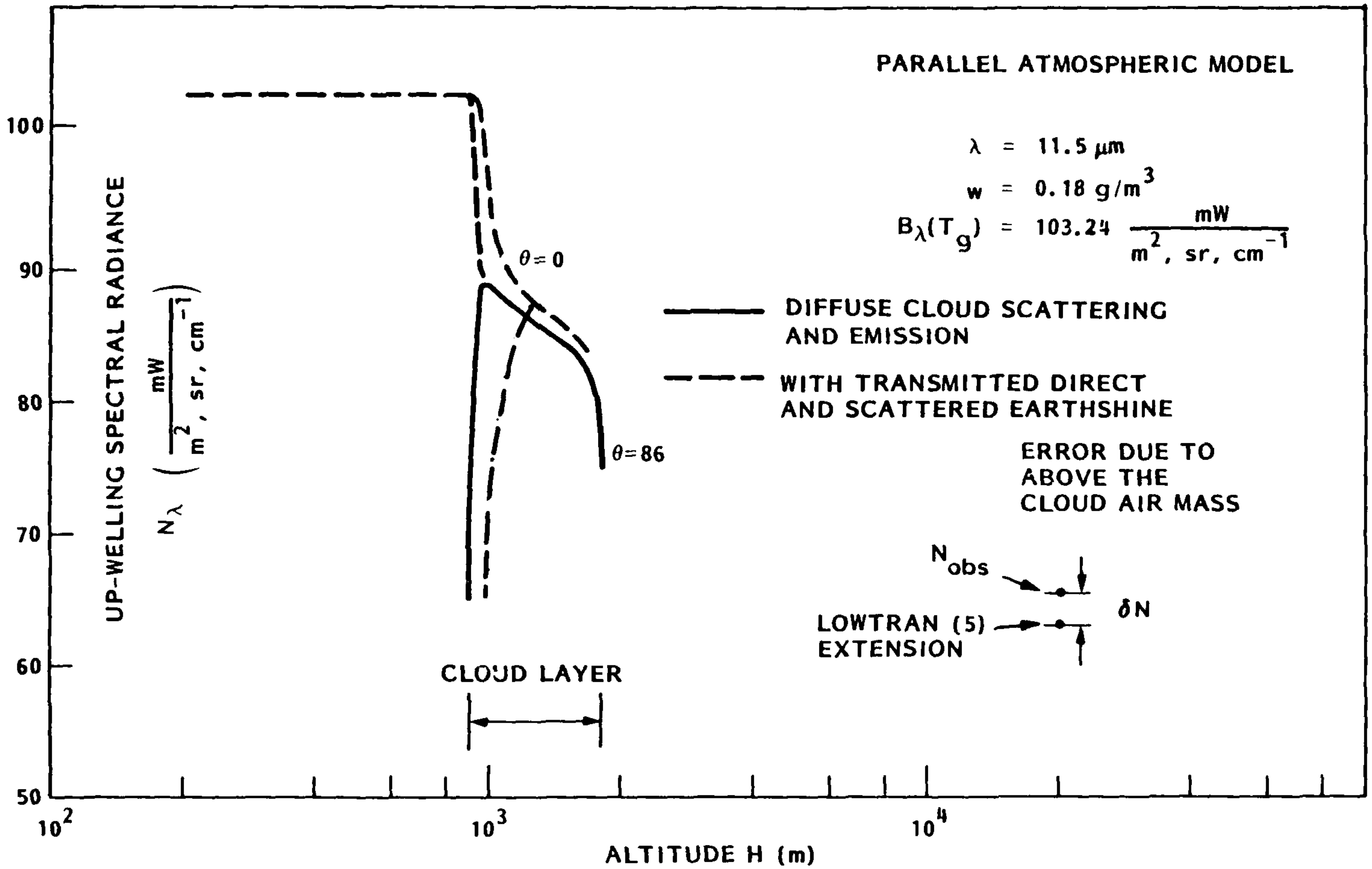


ANGULAR VARIATION OF THE UPWELLING FROM HOMOGENEOUS STRATOCUMULUS CLOUD LAYER

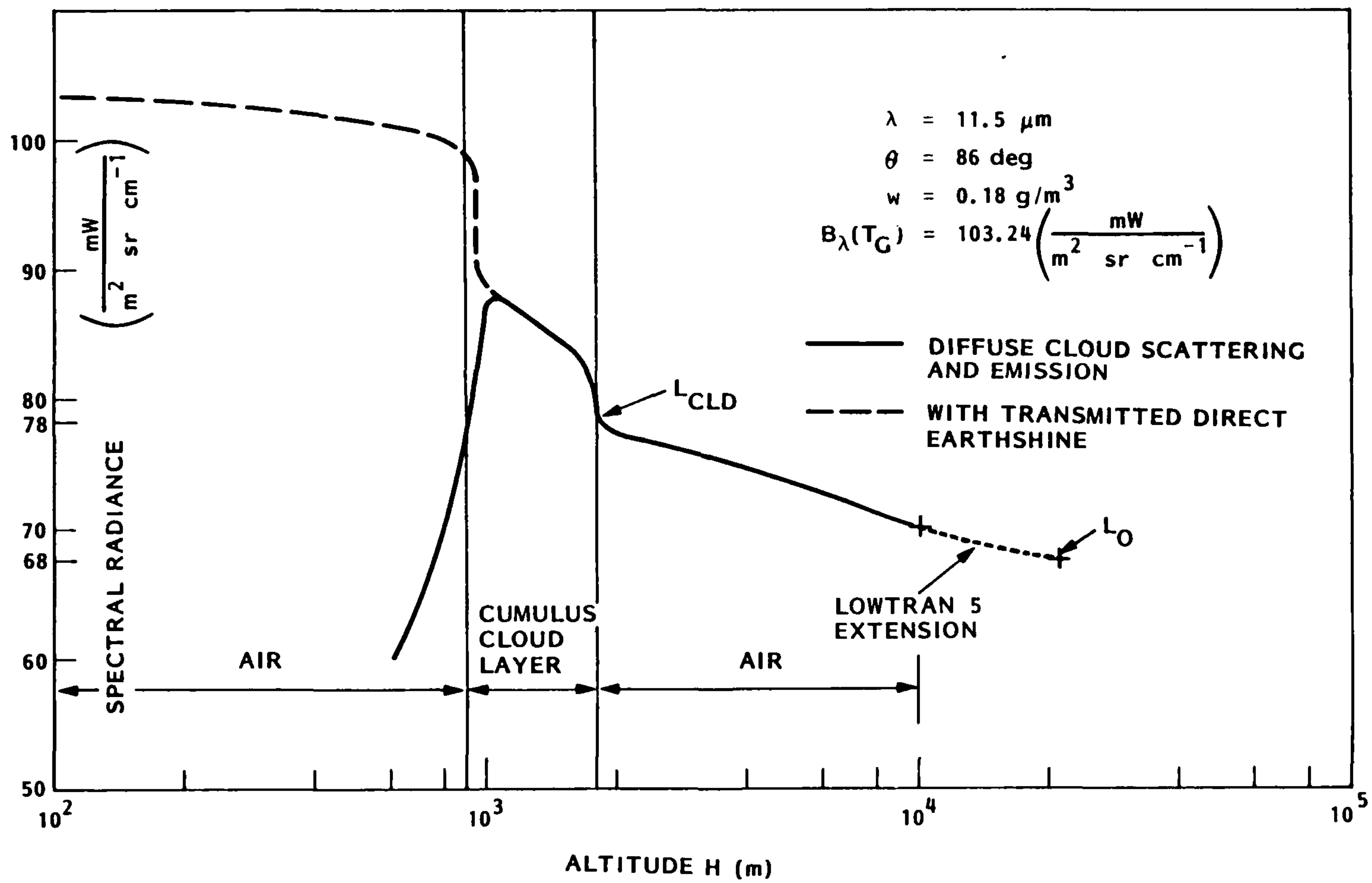
Lockheed



ISOLATED CUMULUS CLOUD LAYER

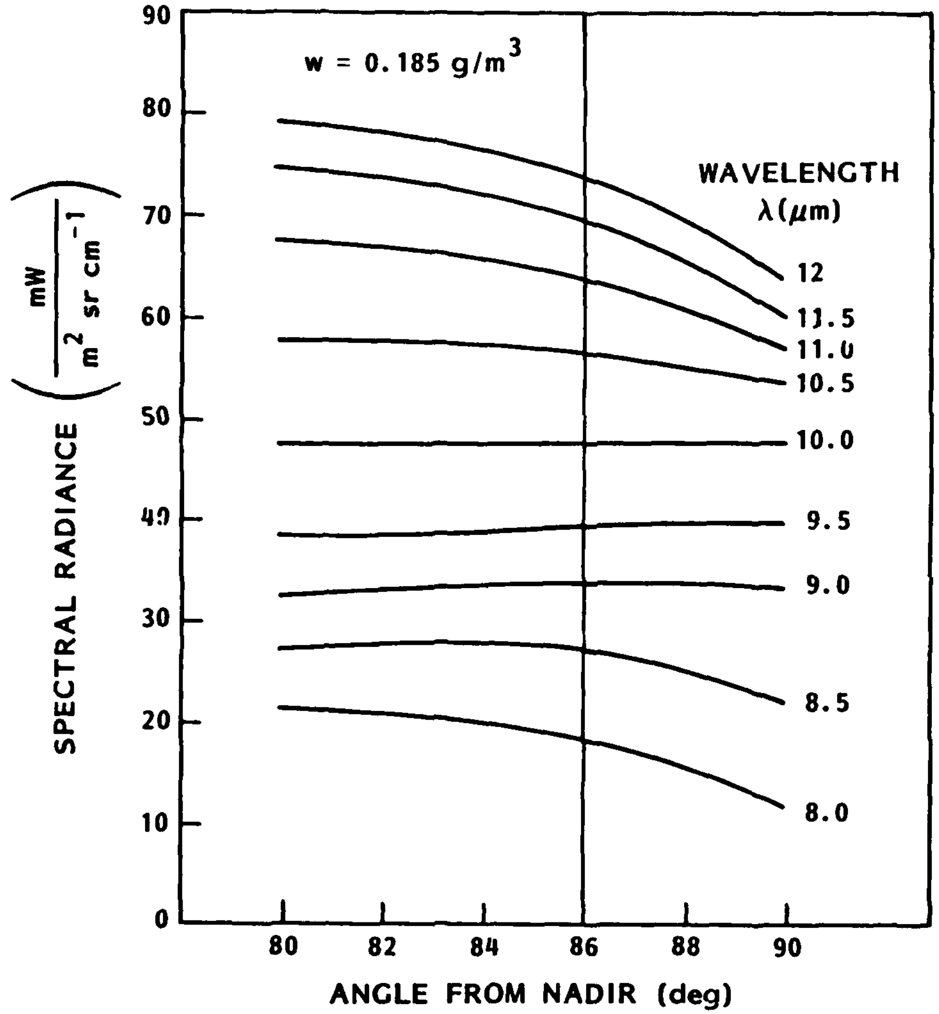


SPECTRAL RADIANCE FOR CUMULUS CLOUD LAYER



SPECTRAL RADIANCE AT H = 10 km FOR ATMOSPHERE PLUS CUMULUS LAYER

Lockheed



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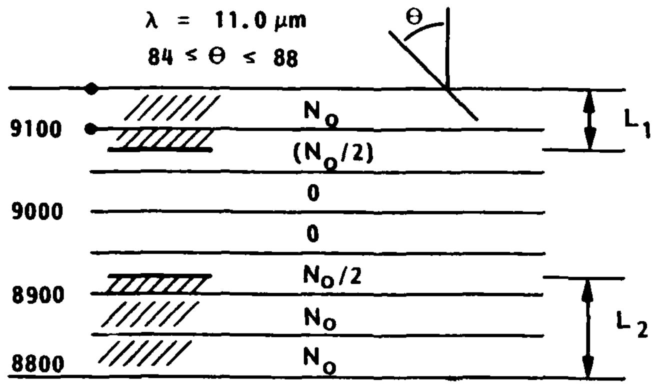
MULTILAYER EFFECTS



- OPTICALLY THIN CIRRUS

$w = 0.005\ g/m^3$, $N_o = 4.09\ 10^{-3}\ \#/cm^3$ } SINGLE LAYER

TWO OPTIONS

a: TWO-LAYER WITH $N_o = 4.09\ 10^{-3}\ \#/cm^3$

b: TWO-LAYER WITH $N_o = 7.15\ 10^{-3}$ (COLUMN DENSITY IS CONSERVED)

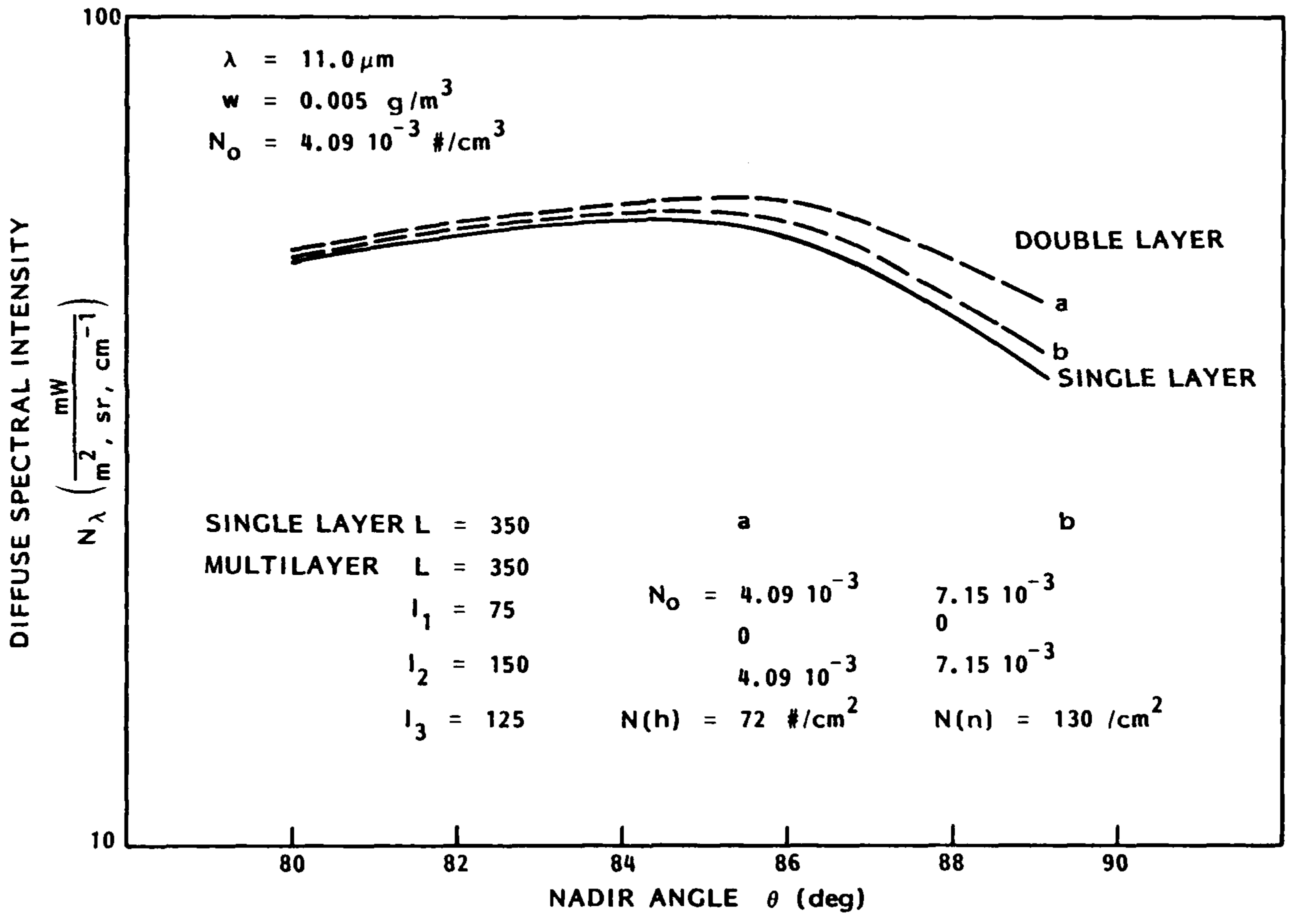
RESULTS

OPTION a:	MULTILAYER	~ 10%	BRIGHTER	AT	Θ = 86
	TRANSMISSIVITY	2.5%	HIGHER	AT	Θ = 86
	EMISSIVITY	5%	HIGHER	AT	Θ = 86
b.	MULTILAYER	~ 5%	BRIGHTER		
	TRANSMISSIVITY, EMISSIVITY	CONSTANT			

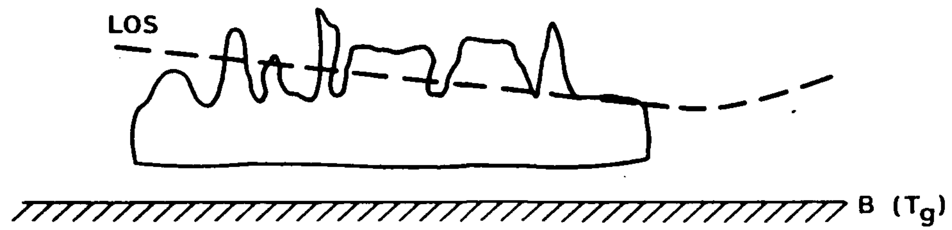
- OPTICALLY THICK CUMULUS (NOT YET STUDIED)

MULTILAYER EFFECTS

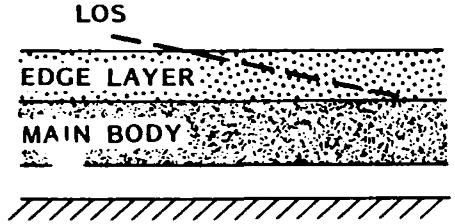
CIRRUS LAYER WITH U.S. STANDARD ATMOSPHERE

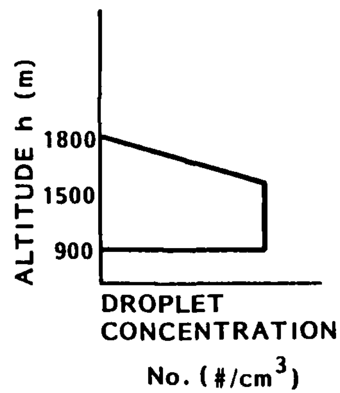


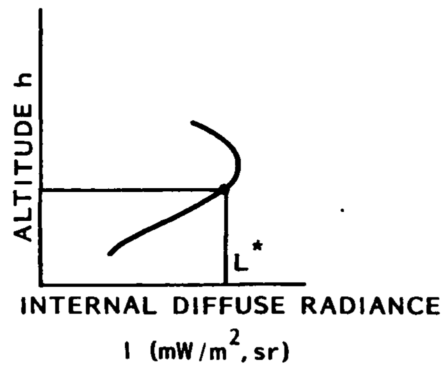
SIMULATION OF CLOUD EDGE EFFECTS

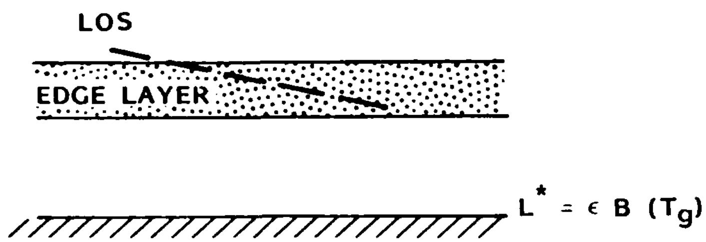


EQUIVALENT DOUBLE
MEAN LAYER









OBTAIN N^e_{diff} (λ, Z) AND t^e (λ, Z)
FROM THE ITERATIVE EXACT SOLUTION
(MULSCT) CODE

SPECTRAL RADIANCE AT H = 10 km FROM CUMULUS EDGE LAYER

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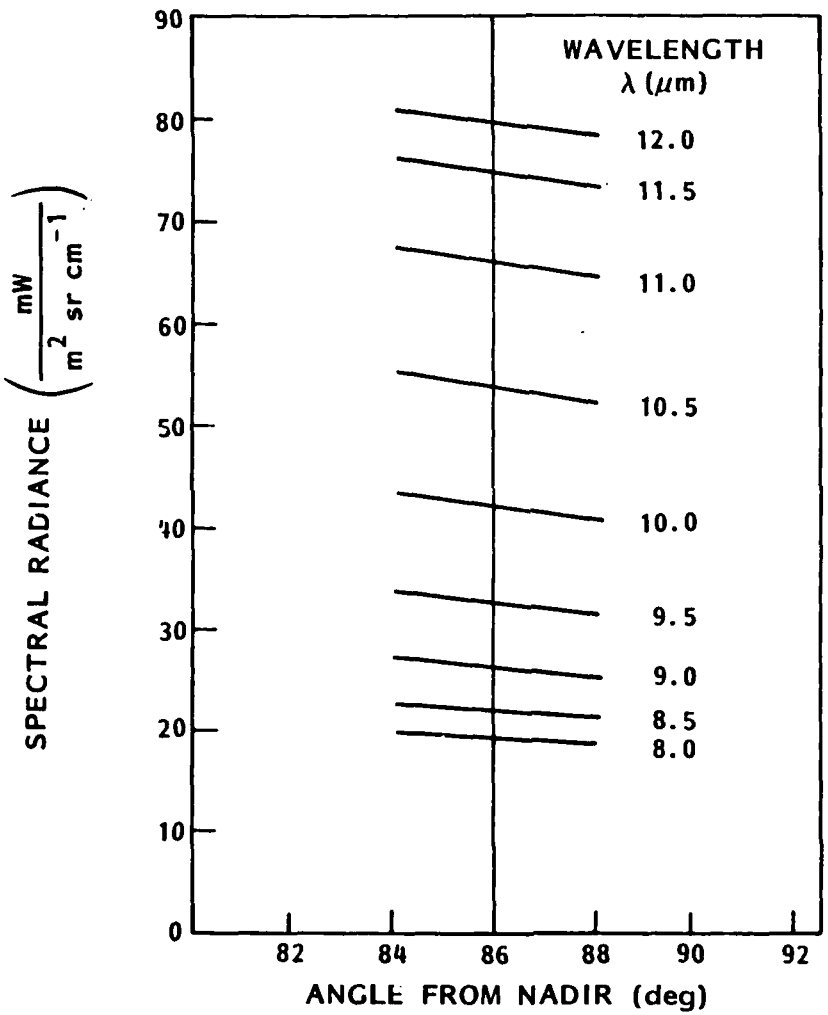

COMPUTATIONAL "ENGINEERING" MODEL FOR $[8 \leq \lambda(\mu m) \leq 12]$ BAND

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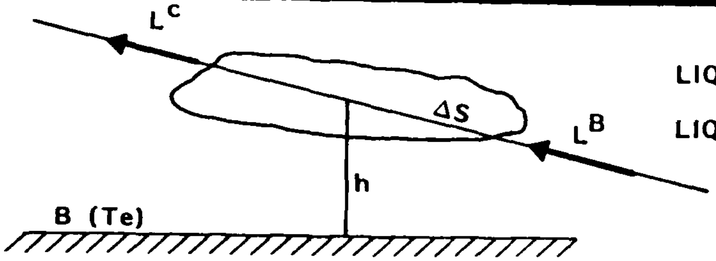


LIQUID WATER DENSITY: ρ_o (g/cm^3)

LIQUID WATER PATH: $Z = 10^6 \int_{\Delta S} \rho_o \Delta S \quad (g/m^2)$

CLOUD RADIANCE

$$L^C(Z) = \underbrace{\alpha N^C(Z)}_{\text{DIFFUSE}} + \underbrace{t^C(Z)\, L^B}_{\text{DIRECT}} \qquad (mW/m^2, sr)$$

WHERE

α = ENHANCEMENT FACTOR DUE TO SCATTERED AIRSHINE

$N^C(Z)$ = EFFECTIVE BAND AVERAGED UPWELLING CLOUD RADIANCE

$t^C(Z)$ = TRANSMITTANCE

} TABULAR INPUT FROM ITERATIVE MULSCT CODE

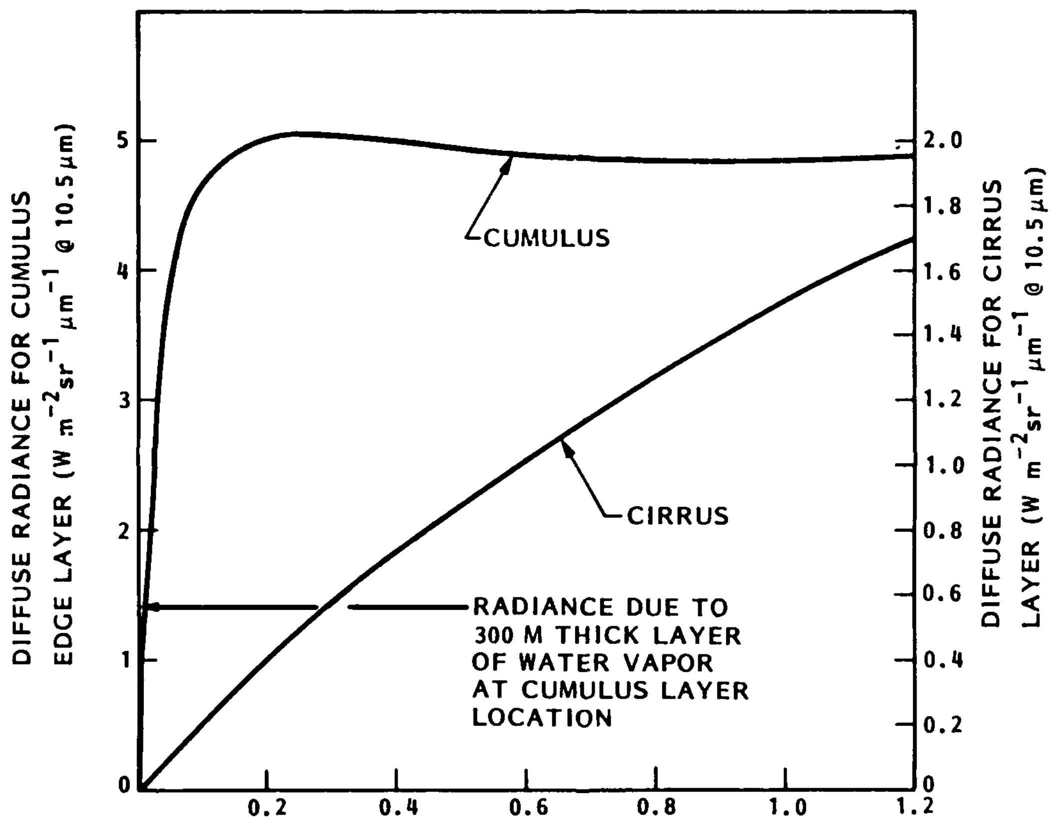
NOTE: TRANSPORT APPROXIMATION ALSO MAY BE USED TO CALCULATE TRANSMITTANCE

$$t^C(Z) = \left[t^C(Z_o)\right]^{(Z/Z_o)}$$

WHERE $$t^C(Z_o) = \exp\left\{-\left[k_a + k_s(1-\bar{\mu})\right]\frac{Z_o}{\rho_o}\right\}$$

$k_a, k_s, \bar{\mu}$ AVERAGED MIE COEFFICIENTS

DIFFUSE CLOUD RADIANCE AS A FUNCTION OF NORMALIZED LIQUID WATER PATH



CIRRUS: $z_o = 25 \text{ g m}^{-2}$

CUMULUS: $z_o = 164 \text{ g m}^{-2}$

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SUMMARY

CLOUD RADIANCE MODEL HAS BEEN DERIVED BASED ON RIGOROUS SOLUTION OF THE MULTIPLE SCATTERING TRANSFER EQUATION UTILIZING MIE THEORY AND REALISTIC ATMOSPHERIC CLOUD MODELS

NUMERICAL SOLUTION IN THE 8 TO 12 SPECTRAL REGION, AND ENGINEERING SOLUTIONS HAVE BEEN OBTAINED FOR IRST APPLICATION. MAJOR CONCLUSIONS ARE:

- MULTIPLE SCATTERING SHOULD BE INCLUDED IN MODELING
- EARTH RADIATION
  - NEGLIGIBLE EFFECTS FOR OPTICALLY THICK CUMULUS
  - SIGNIFICANT RADIATION SOURCES FOR CIRRUS
- AIRSHINE
  - CONTRIBUTES TO PATH RADIANCE
  - SECOND-ORDER CORRECTION FOR ISOLATED CLOUD LAYER
- SHALLOW ANGLE
  - EFFECTIVE AIR MASS: DARKENING – BRIGHTENING EFFECTS
  - DIRECT EARTHSHINE: SHOULD BE REMOVED
- SPECTRAL VARIATION
- MULTILAYER EFFECTS
  - 5 ~ 10% BRIGHTENING DUE TO MULTIPLE SCATTERING
- EDGE LAYER
  - WILL ENHANCE TRANSMISSIVITY (FORWARD SCATTERED SOLAR RADIATION MAY CONTRIBUTE)
  - PROBABLE SOURCE FOR STRUCTURE

COMPLETE NUMERICAL SOLUTION FOR OTHER SPECTRAL REGION (VISIBLE...)

AD-A152 735 PRESENTATIONS AT THE TRI-SERVICE CLOUD MODELING WORKSHOP (2ND) HELD AT TH..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA E BAUER AUG 84 IDA-M-9-VOL-1 3/7

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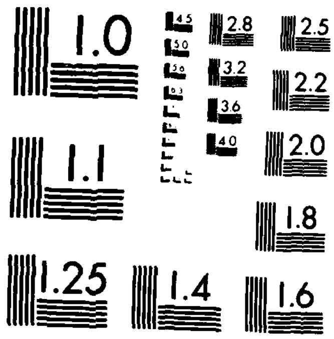

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

INFRARED CLOUD BACKGROUNDS AND SENSOR PERFORMANCE

W.J. Tropf
A. N. Vavreck
John Hopkins University
Applied Physics Laboratory

B. J. Sandford
J. H. Schummers
Air Force Geophysics Laboratory

J. Schroeder
ONTAR Corporation

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W. J. Tropf, A. N. Vavreck
The Johns Hopkins University Applied Physics Laboratory
Laurel, MD 20707

B. P. Sandford, J. H. Schummers
Air Force Geophysics Laboratory
Hanscom AFB, MA 01731

J. Schroeder
ONTAR Corporation
Brookline, MA 02146

Abstract

The performance of an infrared sensor may be greatly affected by cloud clutter. The Johns Hopkins University Applied Physics Laboratory, as part of the Naval Sea Systems Command's Wide Area Guidance and Control Program, is investigating infrared backgrounds and missile seeker signal processing. Clouds are a potentially significant clutter source for both horizontal and down-viewing sensors. A library of representative cloud imagery has been assembled from data taken by the Airborne Measurements Branch, Infrared Technology Division of the Air Force Geophysics Laboratory. Typical scenes include horizon scans with a foreground cloud deck, cloud formations (e.g. cirrus, alto-cumulus, cumulo-nimbus, cirro-stratus, etc.) and terrain background partially obscured by clouds.

These data have been analyzed to characterize clouds in terms of their spatial properties such as size, intensity, contrast and edge sharpness. This includes:

- o Scene statistics - the mean, variance, or higher moments, are used to determine the variation within a scene;

- o Power spectral density - the frequency distribution of clutter power (spatial correlation length can be found from the Fourier transform of the power spectral density);
- o Image processing and enhancement techniques - properties such as slopes, local averages, textures analysis, and edge detection are examined to determine scene content.
- o Bandpass filtering analogous to that used by scanning infrared seekers;

This paper will expand on the results presented at the 1983 Tri-Services Infrared Background Symposium (MITRE October 1983). New methods to characterize cloud imagery and to predict sensor performance against clutter backgrounds will be presented and discussed.

1.0 *Introduction*

Future Naval air defense missiles will include an infrared guidance mode. Applications of infrared missile guidance in this mission include: 1. avoiding ECM, 2. improving high-altitude missile dynamics, and 3. countering low target radar cross section. The Naval Sea Systems Command Wide-Area Guidance and Control Exploratory Development Program (conducted by The Johns Hopkins University Applied Physics Laboratory) has recently initiated a study of the capability of advanced highly sensitive infrared seekers to acquire targets under high clutter conditions. Long range detection of air vehicle targets at both high and low altitudes is a goal of this work. The effort includes both the development of signal processing techniques and the evaluation of signal processing against realistic infrared backgrounds. This paper is the second report of initial results from this work.

Although terrain backgrounds have been extensively studied over the past several years, the effects of atmospheric clouds on sensor performance is an area that has not been fully investigated. Clouds formed by atmospheric water vapor and ice can reduce target visibility, ranging from partial obscuration to total occultation, and consequently reduce sensor performance. Of equal importance are limitations arising from viewing a target against a cloud background or a mixture of clouds, sky and terrain. This paper discusses these limitations and presents analysis which characterize clouds in terms of their spatial properties. The data used for this work were acquired by the Airborne Measurements Branch of the Air Force Geophysics Laboratory (AFGL).

2.0 AFGL Cloud Data

The Air Force Geophysics Laboratory operates an instrumented NKC-135A aircraft to acquire target and background signature data. This system includes a number of spectral, radiometric, and spatial instruments capable of making state-of-the-art inflight measurements. Among these is a calibrated infrared mapper (FLIR) which is used to obtain absolute radiance imagery in the 8-14 μm region.

Since 1978 the AFGL has used the FLIR mapper to acquire signature data of air vehicles, ground targets, and background scenes. From the wide variety of available data a digital tape of 31 calibrated scenes was prepared for analysis. These data include cloud deck with horizon, cloud formations, and terrain backgrounds partially obscured by clouds. Table 1 summarizes the basic characteristics of the scenes in terms of the mean and standard deviation of radiance and an approximate correlation length.

Table 1

AFGL Scene Parameters

Correlation Image	AFGL Designation	Scene IFOV	Scene Radiance (W/cm^2/sr)* Mean	Deviation	Scene Length (mrad)
I01	I0504A	0.5 mrad	2.88×10^{-3}	1.62×10^{-4}	18.5
I02	I0510A		3.44×10^{-3}	1.06×10^{-4}	12.0
I03	I0804A		3.25×10^{-3}	3.26×10^{-4}	20.0
I04	I0804B		3.82×10^{-3}	3.46×10^{-4}	24.5
I05	I0101A		3.01×10^{-3}	7.04×10^{-5}	6.8
I06	I0101B		2.89×10^{-3}	1.21×10^{-4}	6.5
I07	I0101C		3.23×10^{-3}	2.37×10^{-4}	16.0
I08	I0103A		1.74×10^{-3}	2.18×10^{-4}	18.5
I09	I0103B		2.80×10^{-3}	1.11×10^{-4}	14.0
I10	I0103C		2.54×10^{-3}	8.84×10^{-5}	7.3
I11	I0901Z		2.25×10^{-3}	1.23×10^{-4}	12.0
I12	I0902A		2.27×10^{-3}	1.45×10^{-4}	4.4
I13	I0102Z		1.11×10^{-3}	1.94×10^{-4}	21.7
I14	I0104A		1.54×10^{-3}	2.14×10^{-4}	19.0
I15	B0104B		1.87×10^{-3}	8.08×10^{-5}*	22.5
I16	I1201A		1.55×10^{-3}	3.02×10^{-4}	25.0
I17	I1201B		2.41×10^{-3}	1.35×10^{-4}	13.5
I18	I1201C		3.13×10^{-3}	2.21×10^{-4}	18.5
I19	I1201D		2.10×10^{-3}	2.52×10^{-4}	21.0
I20	I1201E		2.41×10^{-3}	8.95×10^{-5}	17.5
I21	I2003A	0.1 mrad	4.01×10^{-3}	1.61×10^{-4}	13.7
I122	I2003B		3.98×10^{-3}	1.74×10^{-4}	3.5
I23	I2003C		4.02×10^{-3}	2.05×10^{-4}	4.6
I24	I2003D		3.94×10^{-3}	1.49×10^{-4}	3.2
I25	I2003E		4.09×10^{-3}	1.64×10^{-4}	4.1
I26	I2003F		4.13×10^{-3}	1.33×10^{-4}	3.4
I27	I2003G		4.06×10^{-3}	1.56×10^{-4}	4.0
I28	I2003H		4.28×10^{-3}	1.34×10^{-4}	3.6
I29	I2003I		3.94×10^{-3}	1.22×10^{-4}	3.0
I30	I2503A	0.5 mrad	2.02×10^{-3}	1.86×10^{-4}	20.0
I31	I2503B		1.81×10^{-3}	3.20×10^{-4}	12.0

* 7.84–13.16 μm spectral bandpass except image I15 which is uncalibrated.

3.0 Cloud Edge Characterization

Cloud edges may be a significant source of false alarms. Both the extent and steepness of the edges will contribute to the seeker tracking problem. Our previous paper (Reference 1) used a series of linear directional masks to examine edge properties which showed that these operators are not adequate for delineating edge properties. This paper will use a 3x3 nonlinear Sobel (Reference 2) enhancement operator to investigate cloud edge properties for the four images (Figures 1-4 of Reference 1). The temperature contours for Images I23 and I24 (Figures 3 and 4 of Reference 1) are given for reference in Figures 1 and 2.

A Sobel operator is of the form:

$$T'(i,j) = (x^2+y^2)^{1/2}$$

where

$$X = (c+2f+i) - (a+2d+g)$$

$$Y = (a+2b+c) - (g+2h+i)$$

for a 3x3 neighborhood of pixel T(i,j):

$$\begin{matrix} a & b & c \\ d & T(i,j) & f \\ g & h & i \end{matrix}$$

and the letters a,b, etc. represent the pixel values (e.g., radiance) at the respective positions relative to pixel T(i,j). The results of applying a Sobel operator to Figures 1 and 2 (Images I23 and I24) are shown in Figures 3 and 4. The range in values for the two images was from slightly greater than zero to 24 (Image I23) and 32 (Image I24). However the mean and distribution of values, as shown in Table 2, were similar for both images.

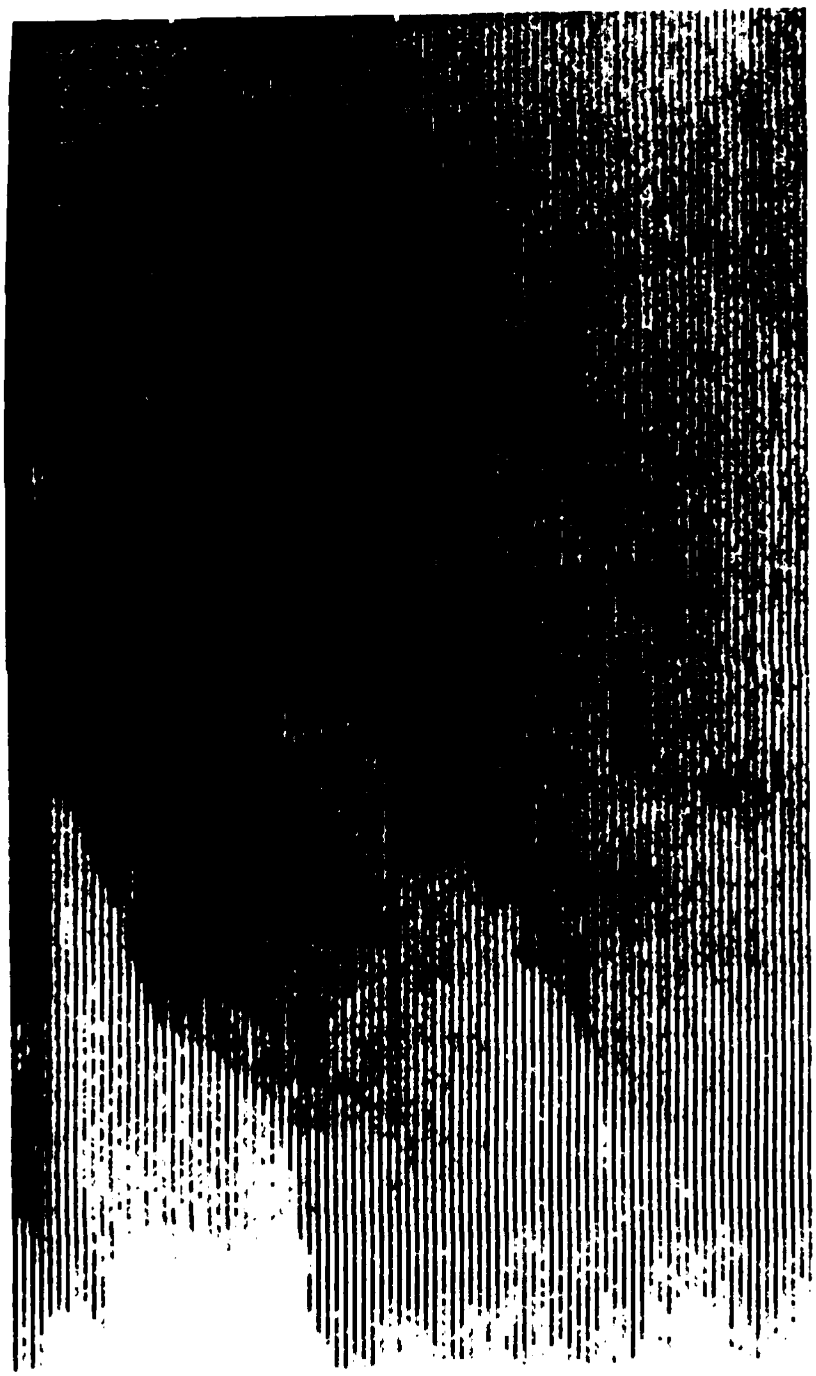
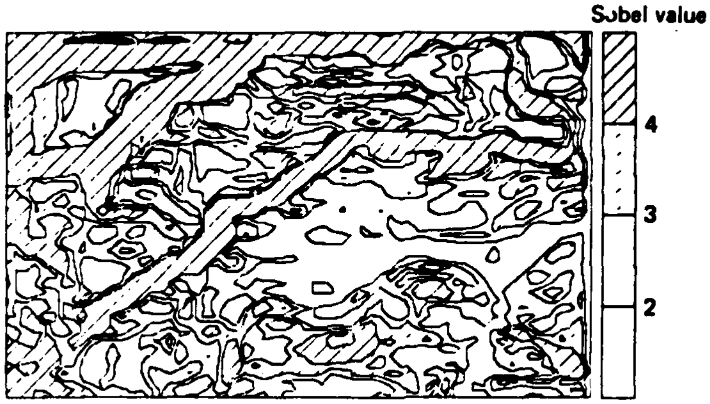
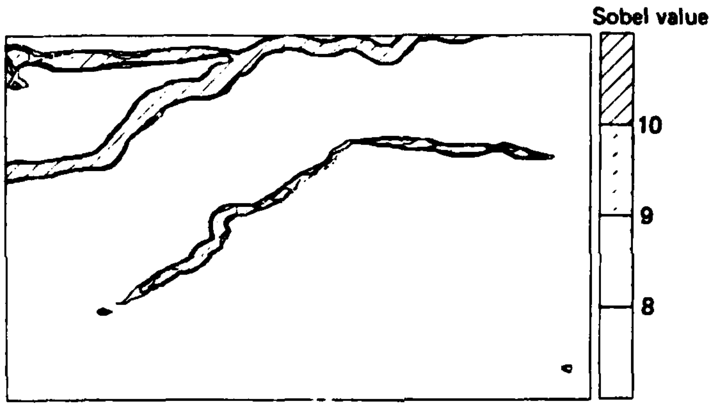


Fig. 1 AFGL image 23.

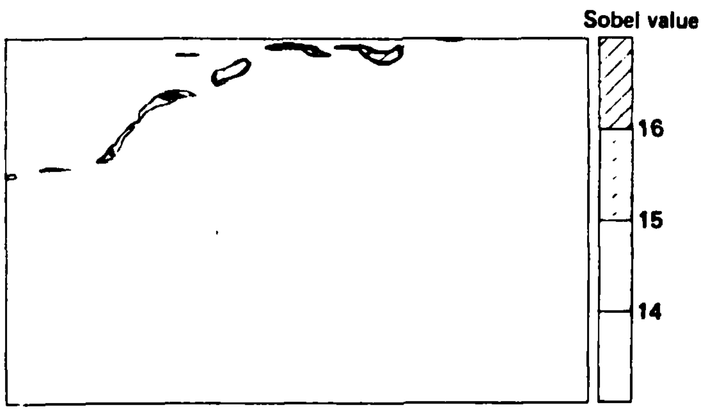
Fig. 2 AFGL image 24.



(a)



(b)



(c)

Fig. 3

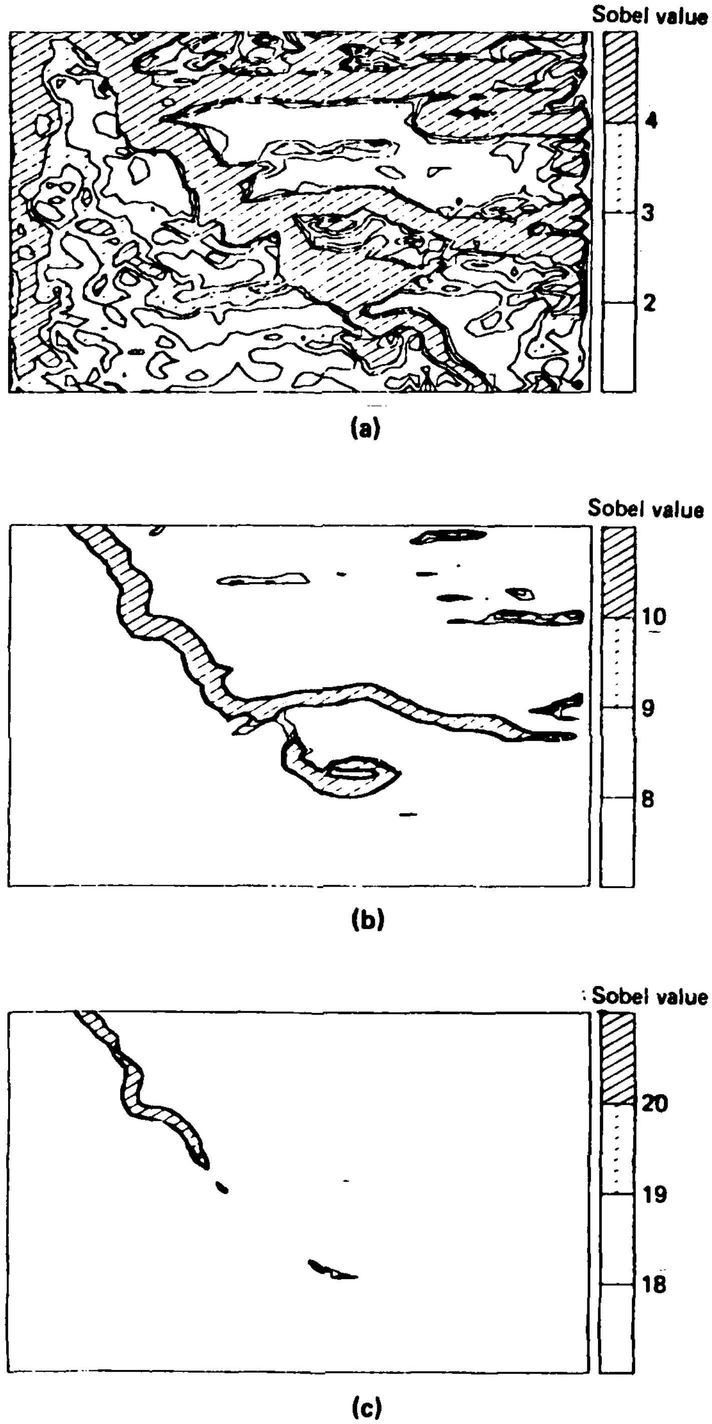


Fig. 4

Table 2. Distribution of Sobel Values

Value of Sobel Operator	Image I23	Image I24	Scene Content
0-2	28%	29%	Intra-cloud
2-4	44	38	Structure
4-6	15	17	
6-10	7	9	
10-20	6	7	Cloud
>20	<<1	<<1	Boundaries
Mean	4.0	4.0	

Figures 3a and 4a give the contours of the two images generated by the Sobel operator for values 2 through 4. In each of these figures all values less than the lower threshold are indicated by the absence of shading while those above the upper threshold are indicated by a high density broken diagonal shading. Figures 3b and 3c for Image I23, and 4b and 4c for Image I24 are plots of the data in Figures 3 and 4 with different threshold values. These plots more clearly show the structure within the cloud formations as well as the magnitude and sharpness of the edges. Both Figures 3 and 4 show a large amount of edge content both within and between the cloud formations. Within a formation the values are small (generally less than 4) and the gradients are not steep. Of interest is that these values are comparable to those within the terrain (see the upper left of Image I23 and the upper central portion of Image I24.

The steepest gradients are, not surprisingly, seen either between the cloud formations or between the clouds and terrain, as is seen in Image I23. The appearance of a thicker contour line in Figures 3 and 4 for this region is the result of several closely spaced contour levels. The values for the edge between the cloud formations range from 4 to 12 while the strong edge at the top of the scenes has values between 4 and 20.

4.0 Seeker Acquisition Performance Using Power Spectral Density Data

In a previous paper (Reference 1) we described AFGL cloud scenes with one-dimensional power spectral densities averaged over all scan lines. Figure 5 shows the power spectra for two typical scenes, one sampled at 0.5 mrad intervals and the other at 0.1 mrad intervals. The k^{-2} (k = spatial frequency in wavenumbers) dependence of clutter power is typical of many backgrounds. The high concentration of noise at low frequencies indicates a preponderance of large features in the scene. An infrared seeker searching for point targets exploits this frequency rolloff of clutter power using a processor (adaptive filter) that blocks the predominately lower-frequency scene noise.

The relatively flat portion of the power spectral density is believed to be the FLIR internal noise floor (see reference 1). When an afocal telescope is used to increase FLIR resolution, the background power spectrum is unchanged while the internal noise power spectrum is lower and spread in spatial wavenumber (i.e., the total internal noise power is unchanged). Hence, the higher resolution scenes give clutter data at higher spatial frequencies.

In Reference 1 we determined the required target irradiance for detection of point clutter in various cloud scenes using the following assumptions:

1) The target signal is an impulse, i.e., the target Fourier transform is flat (to the background cutoff frequency) with a magnitude of $E_t \Delta x$ where E_t is the target irradiance and Δx is the spatial sample interval.

2) A fixed signal-to-noise ratio is used as the threshold, i.e., $(S/N)^2 = 50$ (after filtering) is used as an arbitrary threshold for detection and false alarm rate. (Note that a scene with Gaussian background statistics and 49152 pixels would require a threshold of approximately 16 to insure a false alarm probability of less than 0.1).

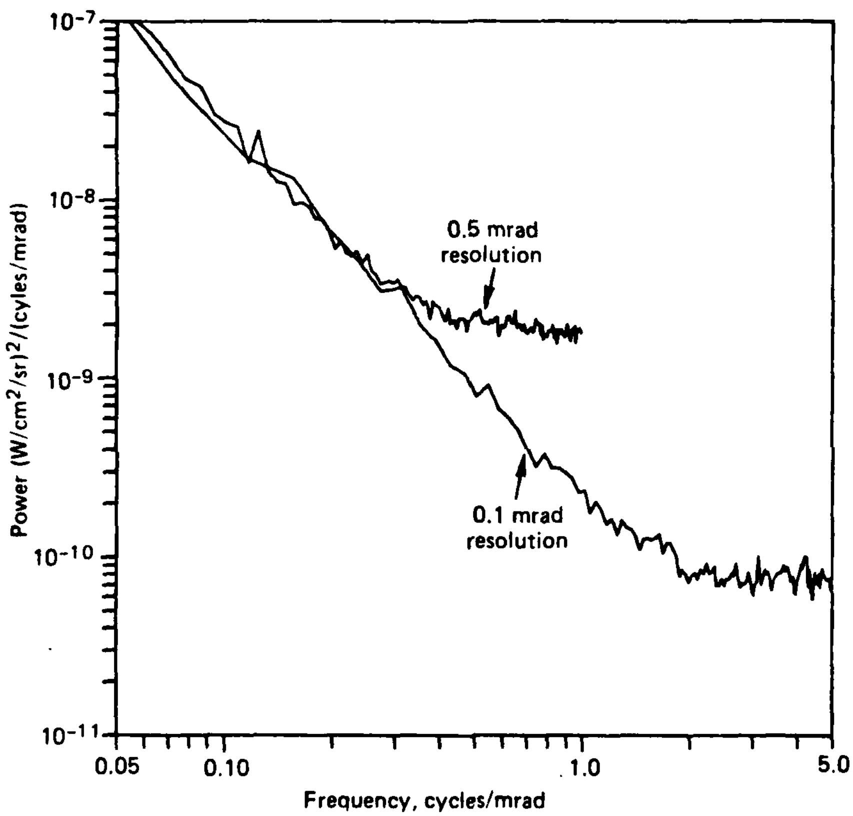


Fig. 5 Scene Power Spectra.

These assumptions were used in Reference 1 to determine the required target irradiance for the cases of an ideal bandpass filter (passing all frequencies for k to kmax, kmax = $1/2\Delta x$) and a matched filter. Furthermore, FLIR noise-limited acquisition range was estimated using the flat portion of the power spectra.

Matched Filter Results

Table 3 summarizes the required target irradiance using a matched filter for 30 cloud scenes. Three results are given: (1) required target irradiance for the scene data (background plus FLIR noise), (2) required target irradiance for FLIR noise only (white noise assumed), and (3) required target irradiance against the background only (i.e., the background power spectral density is extrapolated beyond the FLIR noise floor). The first two results are an extension of those given in Reference 1; the third is new.

Comparison of required target irradiance for the scene data and the FLIR noise level shows that the FLIR noise significantly affects the usefulness of the scene data to determine detection performance in backgrounds. In order to get an estimate of the effect of background alone on detection, scene data power spectral density was used for low wavenumbers and extrapolated with a k^{-2} function to higher spatial frequency. The validity of this extrapolation to 1 cycle/mrad (adequate for examination of 0.5 mrad scenes) is confirmed by examination of power spectral density of high resolution scenes (see Figure 5). This artifical removal of FLIR noise lowers the required target irradiance for detection by a factor of 2.

Comparison of 0.5 mrad scene results with those from 0.1 mrad resolution scenes shows the value of high spatial resolution in clutter suppression. Presuming a k^{-2} dependence of background clutter, the matched filter performance will improve (required target irradiance decrease) as the square of the sensor resolution. Unfortunately, diffraction limits the resolution achievable by small aperture seekers. The diffraction limit of a two-inch aperture is approximately 0.5 mrad at 10 μm .

Table 3
Required Target Irradiance for Material
Filter Detection in Several AFGL Cloud Scenes

Image	IFOV	Scene Description	Required Target Irradiance ($10^{-11}W/cm^2$) Background Plus Noise	FLIR Noise Only	Background Only
I01	0.5 mrad	Down Viewing Cloud	3.98	2.96	1.81
I02		Down Viewing & Water	3.46	2.67	1.53
I03		Down Viewing & Terrain	8.36	6.46	4.80
I04		Down Viewing & Terrain	8.67	6.82	4.67
I05		Clouds & Horizon	3.53	2.73	1.73
I06		Cloud Deck	4.97	3.68	2.95
I07		Cloud Structure	5.53	4.22	3.70
I08		Clouds & Horizon	9.81	8.14	2.94
I09		Monument Valley	4.17	3.21	2.34
I10		Monument Valley	4.09	3.12	2.23
I11		Close Clouds	3.39	2.71	1.50
I12		Close Clouds	3.38	2.72	1.63
I13		Clouds & Horizon	5.29	4.36	2.62
I14		Clouds & Horizon	5.75	4.65	3.01
I16		Horizon & Clouds	6.20	4.62	3.26
I17		Clouds & Terrain	5.20	4.35	2.07
I18		Clouds & Horizon	5.95	4.57	3.02
I19		Clouds & Horizon	5.64	4.34	3.36
I20		Down Viewing Clouds	3.32	2.69	1.40
I31		Clouds Below Horizon	4.54	3.55	3.23
I32		Down Viewing Clouds	4.96	3.86	3.70
21 scene Average	0.5 mrad		5.23	4.12	2.74
I21	0.1 mrad	Structured Clouds	.147	.110	.070
I22		" "	.152	.107	.083
I23		" "	.175	.131	.106
I24		" "	.150	.122	.072
I25		" "	.171	.134	.084
I26		" "	.154	.118	.077
I27		" "	.165	.125	.084
I28		" "	.160	.127	.077
I29		" "	.144	.114	.063
9 scene average	0.1 mrad		.157	.121	.080

One way of testing the validity of this extrapolated data technique is to use the 0.1 mrad resolution scenes with an assumed 0.5 mrad resolution sensor (i.e., only use the background power spectrum out to 1.0 cycle/mrad spatial frequency.) These results are shown in Table 4. This 9 scene average of 2.54×10^{-11} W/cm^2 for the required target irradiance compares closely to the value of 2.74×10^{-11} W/cm^2 obtained from an average of 21 extrapolated scenes with 0.5 mrad resolution (see Table 3). Hence the extrapolation appears valid.

Using characterized scenes (i.e., power spectral densities) for performance analysis gives a good answer for ultimate seeker performance provided the assumptions used are valid. Two principal assumptions likely to be violated are that the scene is (1) stationary and (2) obeys gaussian statistics. The stationary criterion requires the scene-average statistics to be representative of the entire scene: the spatial correlation between scene elements is dependent only on the spatial separation between the points and not in position in the scene. Power spectral density characterization of the scene includes only a measure of scene variance, not higher moments. Complete scene statistics are needed to calculate the threshold-to-scene noise ratio required for detection (i.e., set the false alarm rate).

5.0 Seeker Acquisition Performance Using Butterworth Filters

Required target irradiance can be more accurately calculated by directly filtering the scene. This approach is straightforward, gives false alarm statistics, but unfortunately can not separate FLIR noise from scene contributions in the data.

Table 4
Required Target Irradiance for Detection with 0.5 mrad Resolution Seeker Using 0.1 mrad Resolution AFGL Cloud Scenes

Image	Description	Required Target Irradiance (10^{-11} W/cm^2)
I21	Structured Clouds	2.48
I22	"	2.60
I23	"	3.36
I24	"	2.24
I25	"	2.63
I26	"	2.30
I27	"	2.86
I28	"	2.41
I29	"	1.95
9 Scene Average		2.54

Filtering was performed digitally, on a line-by-line basis, using Butterworth high-pass filters of various orders. Two filters were of particular interest: a first-order filter, which approximates a prewhitening, or matched filter; and a sixth-order filter, which has an extremely sharp cuton, and represents, approximately, a rectangular filter. Figure 6 shows the spectral character of these filters, and demonstrates their effect on a typical image power spectrum. Figure 7 compares an image after high-pass filtering with a sixth-order filter, with the same image after convolution with the template

$$[-1 \quad 2 \quad -1] \quad .$$

Both images were contrast enhanced to roughly equate their means and variances and thresholded at the same level. The convolved image appears very similar to the digitally filtered image, indicating the sharp high-pass character of the sixth-order filter and the similarity of these methods in isolating scene features.

Statistical analysis of images after filtering leads to a determination of the target irradiance required for a constant false alarm rate. In the case of AFGL images, which contain only 49,152 pixels, the false alarm rate is fixed at zero, with the detection threshold set just above the maximum pixel value in the filtered scene. As will be shown, consideration of both positive and negative thresholds is important, especially when high order filters are applied. A negative threshold is set at just below the minimum pixel value of the filtered scene to preclude false alarms.

Table 5 presents required target irradiances for five different images, chosen for their variety of background characteristics. These irradiances are computed with the assumption that a positive detection threshold is set. With a positive threshold, the first-order Butterworth filter does not require as high a target irradiance for detection as a sixth-order filter at the same cuton frequency. With a negative threshold is considered, this is not true. Table 6 gives required target irradiances

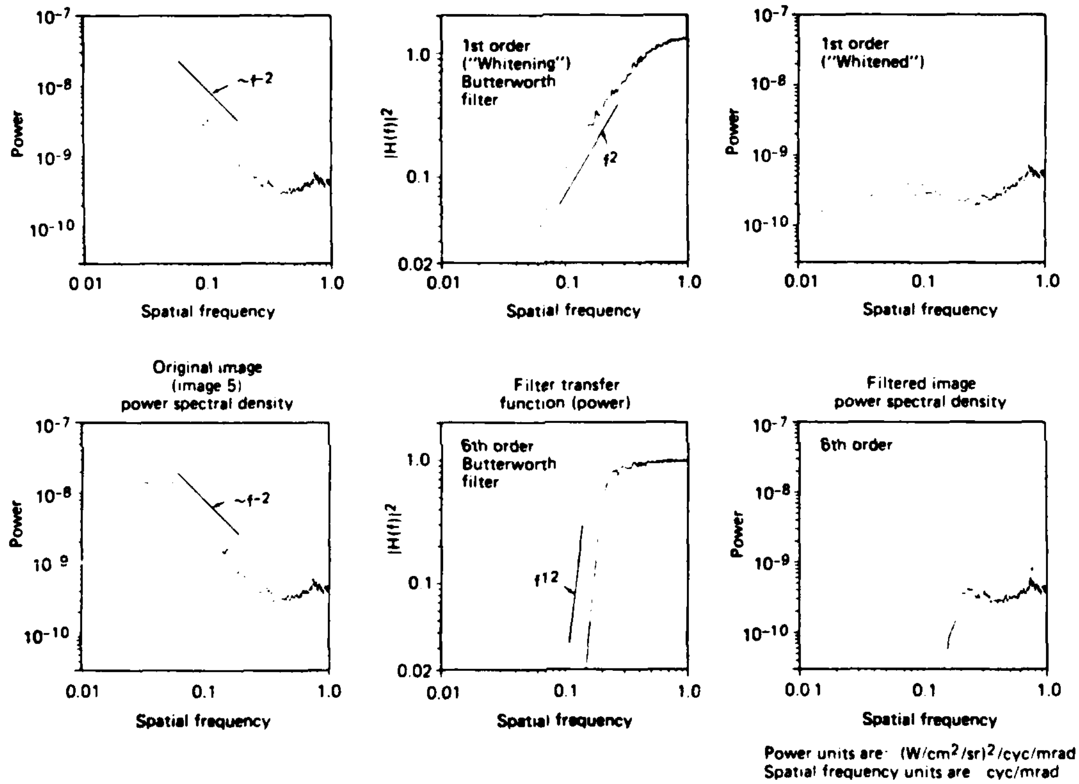
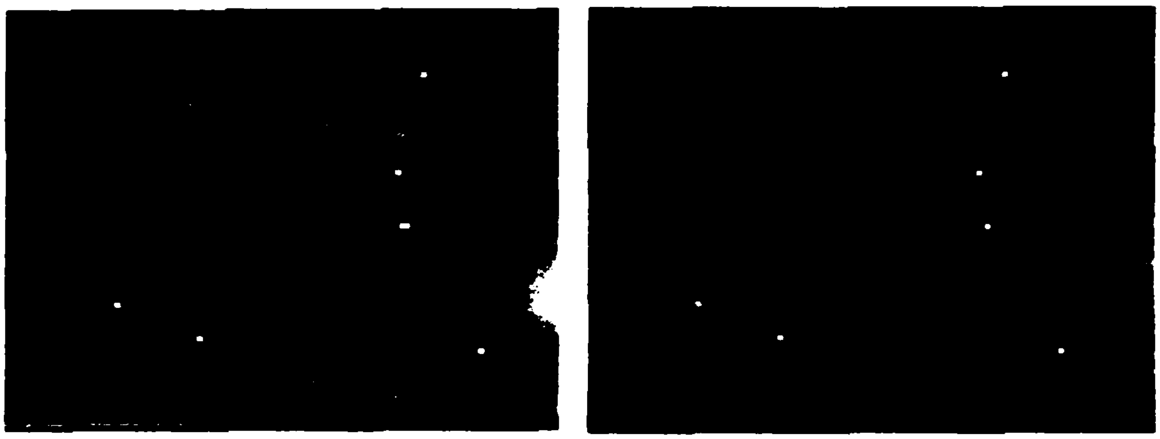


Fig. 6 Digital Filter Characteristics.



a. AFGL image 5 convolved

b. AFGL image 5 filtered

Fig. 7 Image Processing Comparison.

Table 5

Filter Performance Using Positive Threshold, FAR = 0

	1st Order		6th Order	
Image	(T/σ)	E_t,req($10^{-11}W/cm^2$)	(T/σ)	E_t,req($10^{-11}W/cm^2$)
I01	38.2	3.85	28.6	6.87
I05	186.1	7.97	135.9	12.77
I06	75.4	7.76	55.5	12.17
I08	36.3	9.40	17.3	11.72
I09	33.3	4.06	29.8	6.63

Table 6

Filter Performance Using Negative Threshold, FAR = 0

	1st Order		6th Order	
Image	(T/σ)	E_t,req($10^{-11}W/cm^2$)	(T/σ)	E_t,req($10^{-11}W/cm^2$)
I01	28.1	6.51	32.3	3.43
I05	103.2	15.40	62.0	4.75
I06	44.6	11.06	67.8	6.91
I08	18.5	18.32	17.3	6.86
I09	22.6	6.05	29.8	3.71

assuming a negative threshold for detection. Two phenomena contribute to this effect. The first can be seen if an examination of the impulse responses of these filters is made. Figure 8 is a plot of the response of first-and-sixth-order Butterworth high-pass filters to an impulse of height 100 digital counts. The filter cuton in both cases was 0.25 arbitrary frequency units, with the maximum frequency being 1 unit. The extremely sharp negative peak in the response of the higher order filter gives rise to a low impulse absolute amplitude loss after filtering, one comparable to the first-order filter loss.

The second phenomenon involves the sensor internal noise, which is almost certainly gaussian in nature, while the lower frequency background is definitely non-gaussian. As the sixth-order filter passes less of the non-gaussian background than the first order, the sixth-order filtered scene becomes more gaussian and its variance is lower than the first or any lower order filtered scene. This lower variance coupled with a low filter loss, leads to improved performance on the part of the sixth-order filter.

In comparison with calculations earlier in this paper of theoretically determined required target irradiances, Table 7 presents the irradiances in Table 5, given an output signal-to-background noise ratio of 50 in power. The average required target irradiance of these scenes is slightly higher than the level for an ideal matched filter, for both the first and sixth-order cases. Here too, of course, the sixth-order filter requires a lower target irradiance for a zero false alarm rate than the first-order filter with the same cuton frequency.

Required target irradiances have been calculated for first- and sixth-order filters spanning a range of cuton frequencies. The result is plotted in Figure 9, for AFGL image I05, against the ideal bandpass filter required irradiance (see Reference 1). Required target irradiances for the ideal filter case are lower than those for a realizable filter, until higher cuton frequencies are reached. Here, the sixth-order filter, due to its finite slope in the stopband region, improves slightly in its performance over the ideal filter.

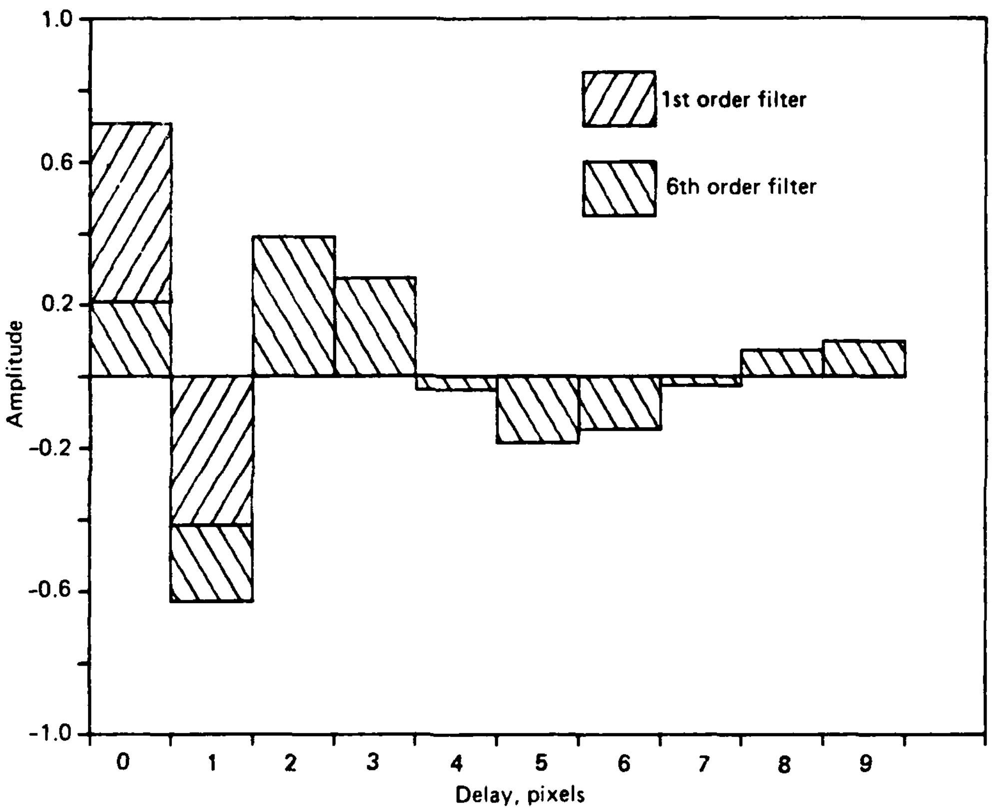


Fig. 8 Filter Impulse Response.

Table 7

Filter Performance Assuming an Output SNR of 50

E_t,req(10^{-11}W/cm^2) @ SNR = 50

Image	1st Order		6th Order	
	+ Thresh	- Thresh	+ Thresh	- Thresh
I01	5.09	6.51	9.08	4.27
I05	4.84	15.40	7.75	4.26
I06	7.36	11.06	10.45	8.05
I08	15.97	18.32	19.92	11.66
I09	5.26	6.05	8.59	4.81
Average	7.70	11.47	11.16	6.61

Average of ideal matched filter case, same images	5.29
Average of ideal Bandpass filter case, same images	5.48

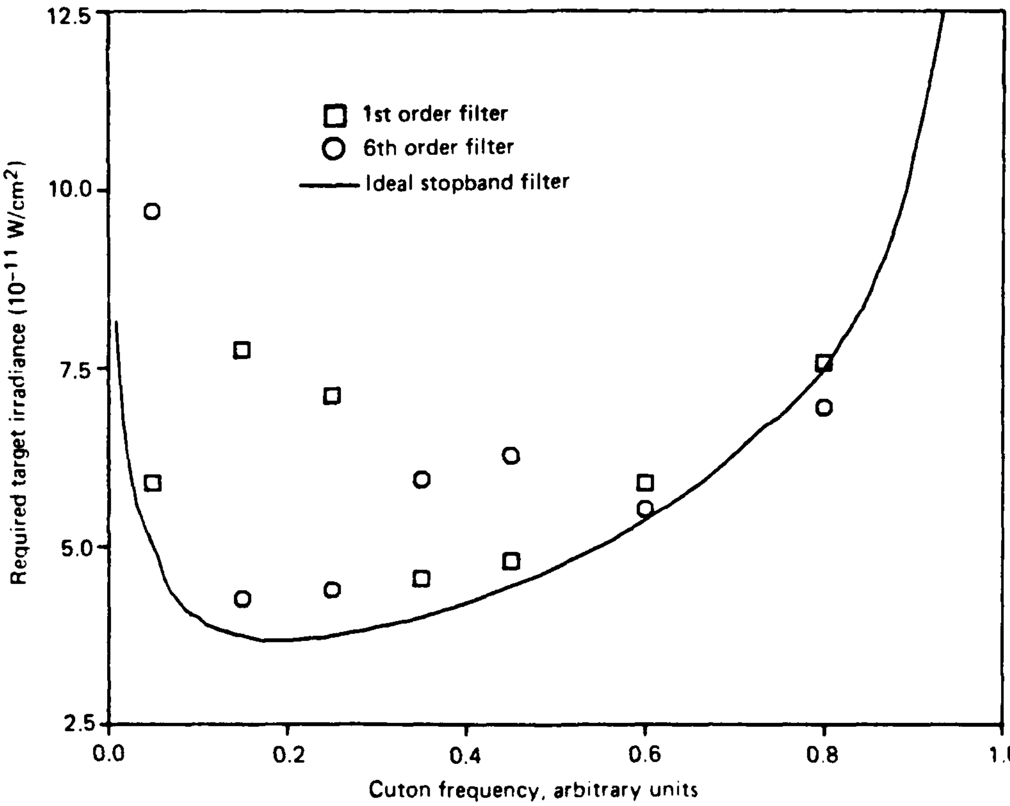


Fig. 9 Filter Performance Versus Cuton Frequency.

Butterworth digital filters of first- and sixth-order appear to be fairly successful as approximations to matched, or prewhitening filters, and ideal bandpass filters, respectively. Because of their real nature and the non-gaussian and non-stationary properties of scenes, these filters do not perform as well as matched ideal filters in suppressing clutter, nor do they relate to each other as in the ideal case. The sixth-order filter performance (assuming a negative threshold is set) is better than the first-order filter performance, whereas theoretically the prewhitening filter outperforms higher-order filters.

6.0 Summary and Conclusions

A data base of cloud imagery for missile seeker performance evaluation has been established and characterized. Included in the characterization is an analysis of sharpness of cloud edges. This work has shown that the boundary between clouds and terrain have very large gradient values. There is also a great deal of edge structure within cloud formations. The magnitude and steepness of intra-cloud edges are, however, small compared to the edges between formations and equivalent to those within terrain observed at long range.

Cloud data are used to estimate the minimum detectable target irradiance of future, high-sensitivity, scanning missile seekers. Both power spectral density characterizations and directly-filtered raw data have been used to determine the impact of scene structure on detection. Comparison of these two techniques showed:

- For a given threshold, and filter type directly-filtered scenes showed higher clutter compared to using processed data

- Directly-filtered scenes required higher thresholds than that expected assuming Gaussian statistics to achieve a given false alarm rate. There was a large scene-to-scene variation in the threshold required with directly filtered scenes.

Matched filters give the best clutter suppression when the scenes are characterized by their power spectral density. Ideal high pass filters approach the performance of a match filter, but are never better. Using directly-filtered images the reverse is true: sharp cuton bandpass filters perform better than 'whitening' filters. This result will be investigated further.

Finally correlation between steep gradients in scenes found by edge detection and high scene clutter after direct bandpass filtering has been made. This connection will be further investigated to determine the utility of image characterization in making detection estimates in clutter.

This work will continue with further investigation of filter performance on an expanded data base. Additional discrimination techniques, such as time-domain pulse-shape analysis, will be explored.

References

1) J. Schroeder, J.H. Schummers, B. P. Sandford, W.J. Tropf, Infrared Cloud Backgrounds (U), Proceedings of the Tri-Services Infrared Backgrounds Symposium (U). AFGL-TR-84-0094.

2) W.K. Pratt, Digital Image Processing, John Wiley & Sons, New York 1978.

Infrared Cloud Backgrounds and Sensor Performance

W. J. Tropf, A. N. Vavreck, B. P. Sandford,
J. H. Schummers, J. Schroeder

Infrared Cloud Backgrounds and Sensor Performance

This Presentation is UNCLASSIFIED.

INFRARED BACKGROUND PROCESSING INVESTIGATION

INTRODUCTION

NEEDED CAPABILITY	INFRARED GUIDANCE MODE AS COUNTER TO AIRCRAFT RCS REDUCTION
TASK OBJECTIVE	DETERMINE USEABLE SEEKER SENSITIVITY FOR ACQUISITION OF AIRCRAFT TARGETS IN CLUTTER

Background Clutter Suppression Investigation

- Background Scene Characterization
- Signal Processing Model Definition
- Algorith Performance Evaluation

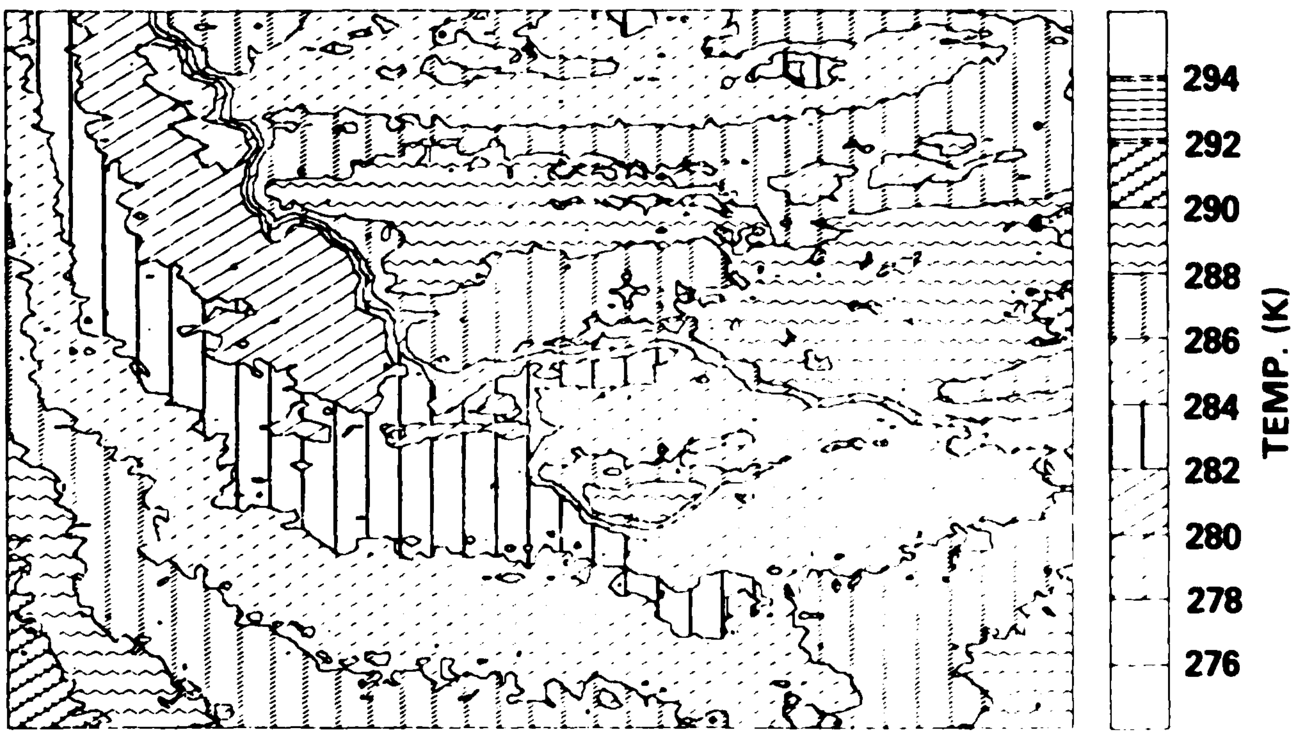
Scene Characterization

- Visual/Temperature Classification

  Image Restoration
- Edge Detection
- Statistics
- Power Spectral Density

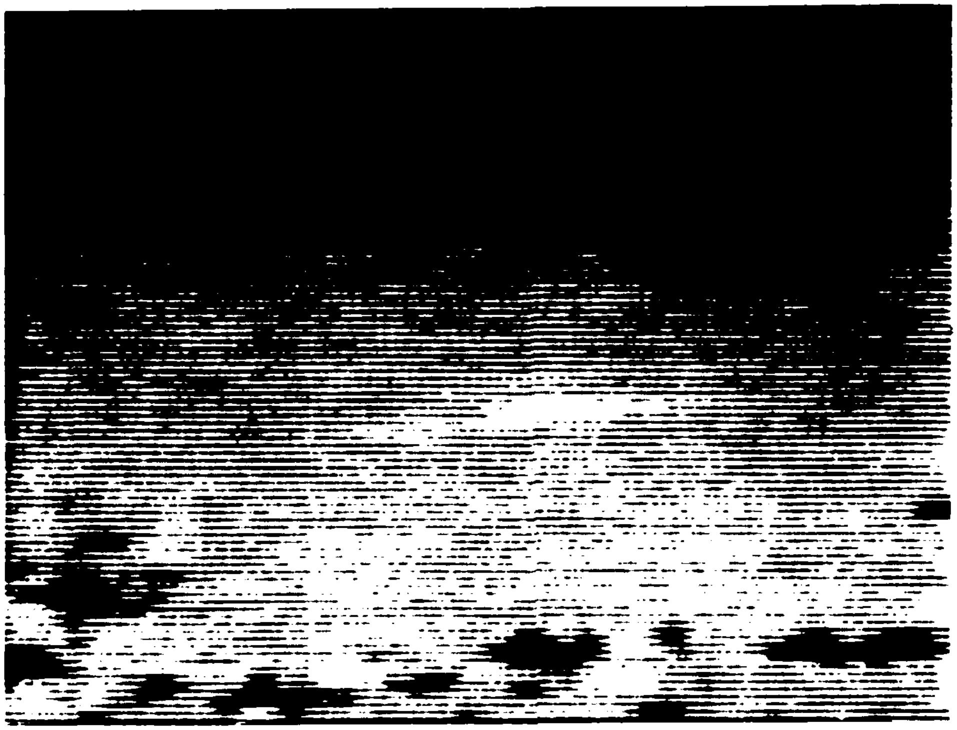
AFGL IMAGE 24 GREY SCALE

AFGL IMAGE 24 TEMPERATURE MAP



BACKGROUND DATA ARTIFACTS

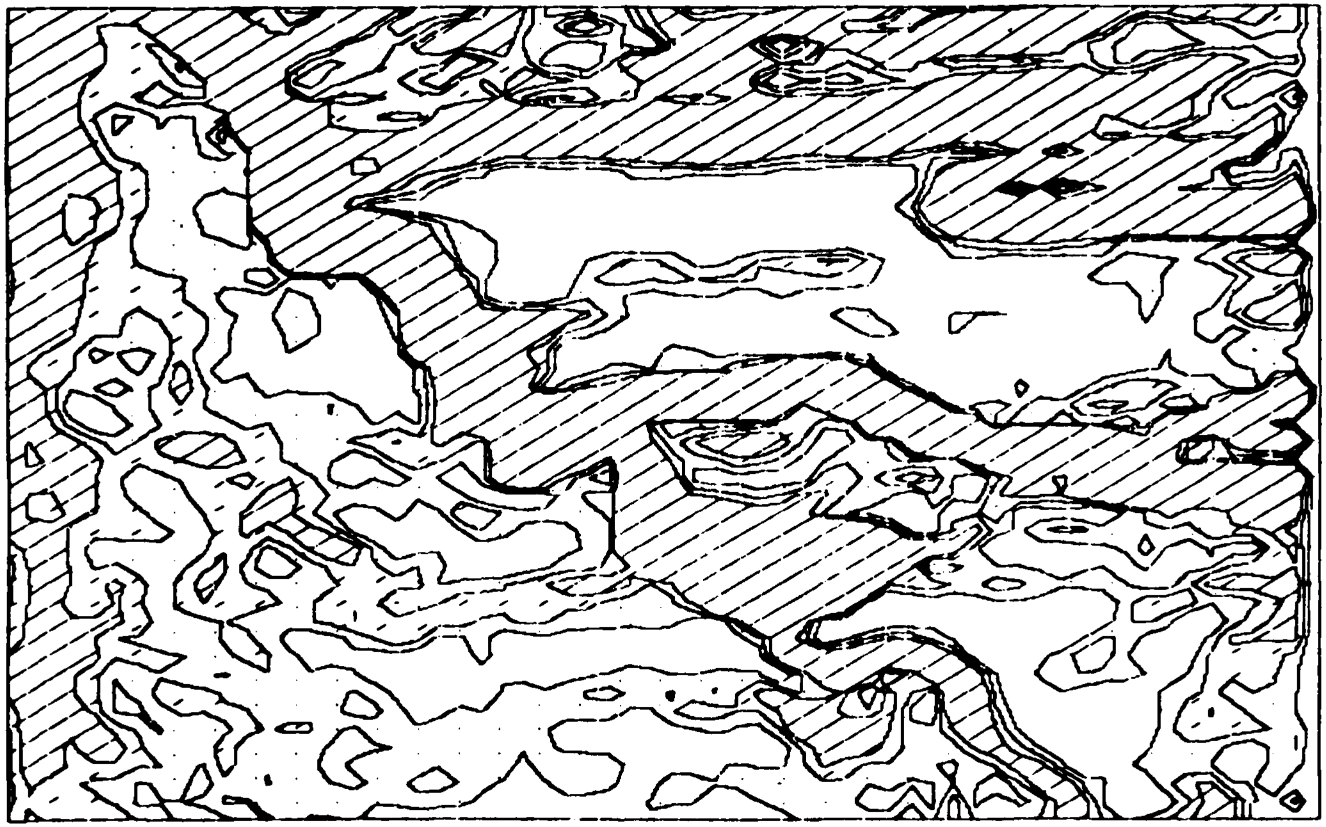
- NOISE
- BAD DATA
  - SCAN LINE DROP OUT (SYNCHRONIZATION PROBLEM)
  - DETECTOR OR DATA ACQUISITION MALFUNCTION
- CHANNEL SCALE OR GAIN MISMATCH
- GEOMETRIC DISTORTION
- VIGNETTING
- MULTIPLE - CHANNEL SPATIAL REGISTRATION



AFGL IMAGE 5 (UNRESTORED)

AFGL IMAGE 5 (RESTORED)

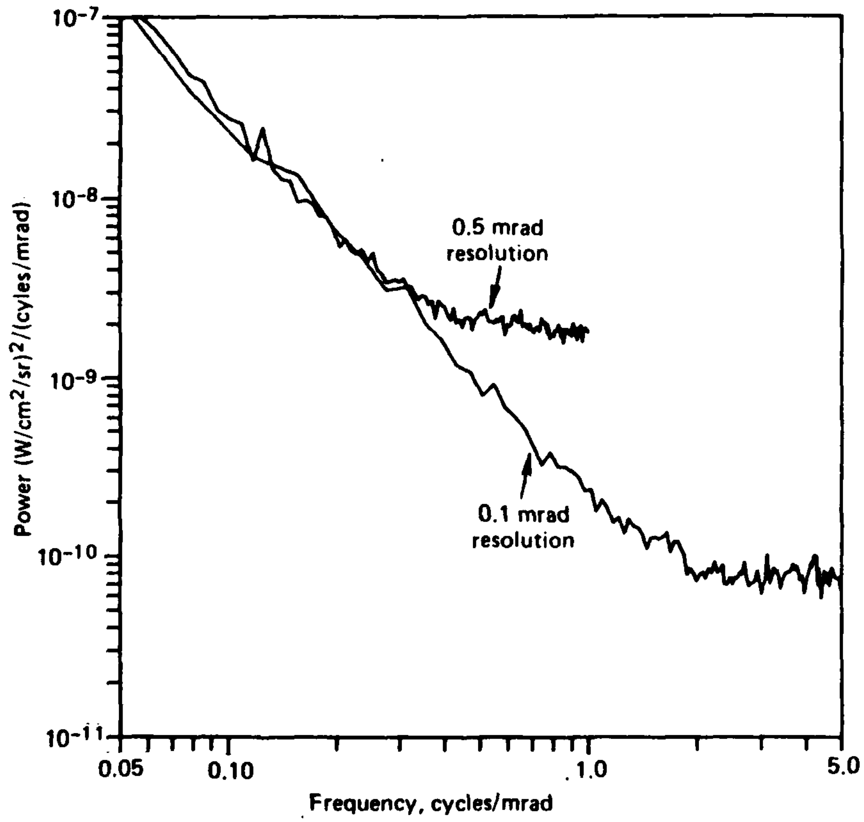
EDGE DETECTION BY SOBEL OPERATION
AFGL IMAGE 24



SOBEL VALUE

BASE < 5.0

SCENE POWER SPECTRA



Signal Processing Model Development

- Filter Scenario Development

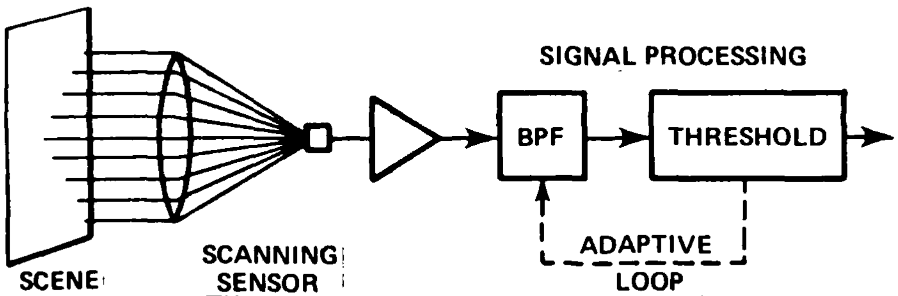
  Matched Filter

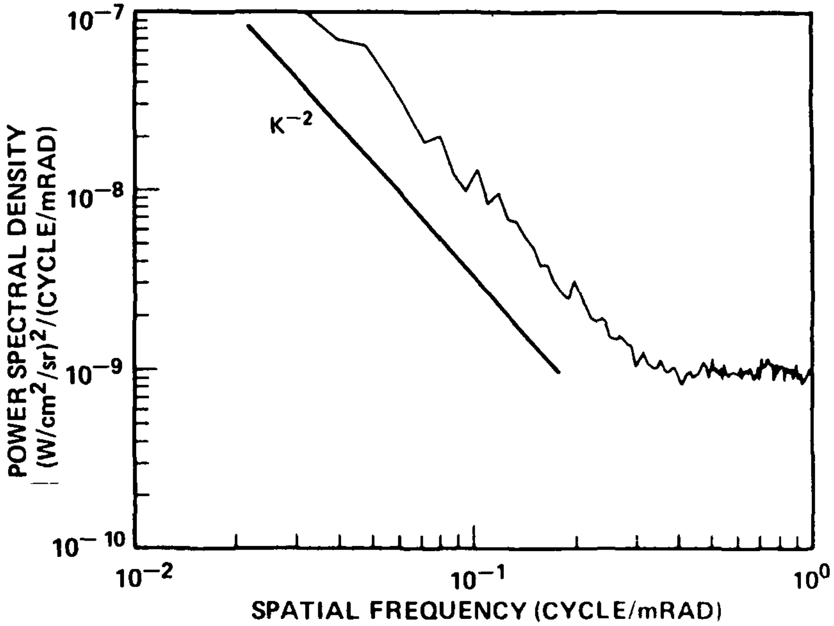
  Rectangular Filter

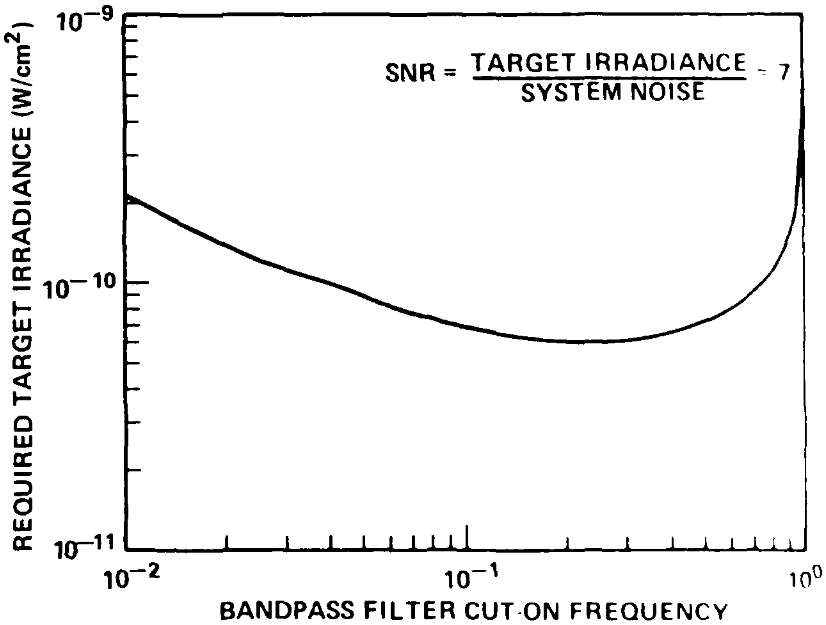
- Ideal Filter Performance Evaluation

SCANNING IR SENSOR PERFORMANCE IN BACKGROUND

AFGL FLIR SCENE
(OVERCAST CLOUD DECK VIEWED FROM 35 KFT)







MATCHED FILTER PERFORMANCE

(USING BACKGROUND POWER SPECTRAL DENSITY DATA)

IMAGE	IFOV	REQUIRED TARGET IRRADIANCE (10^{-11} W/cm^2)*		
		BACKGROUND PLUS NOISE	SENSOR NOISE ONLY	BACKGROUND ONLY
101	0.5 mrad	3.98	2.96	1.81
105	↓	3.53	2.73	1.73
106	↓	4.97	3.68	2.95
108	↓	9.81	8.14	2.94
109	↓	4.17	3.21	2.34
21 SCENE AVERAGE	0.5 mrad	5.25	4.12	2.71
121	0.1 mrad	0.147	0.110	0.070
124	↓	0.150	0.122	0.072
9 SCENE AVERAGE	0.1 mrad	0.157	0.121	0.080

* $(T/N)_{out} = 50$

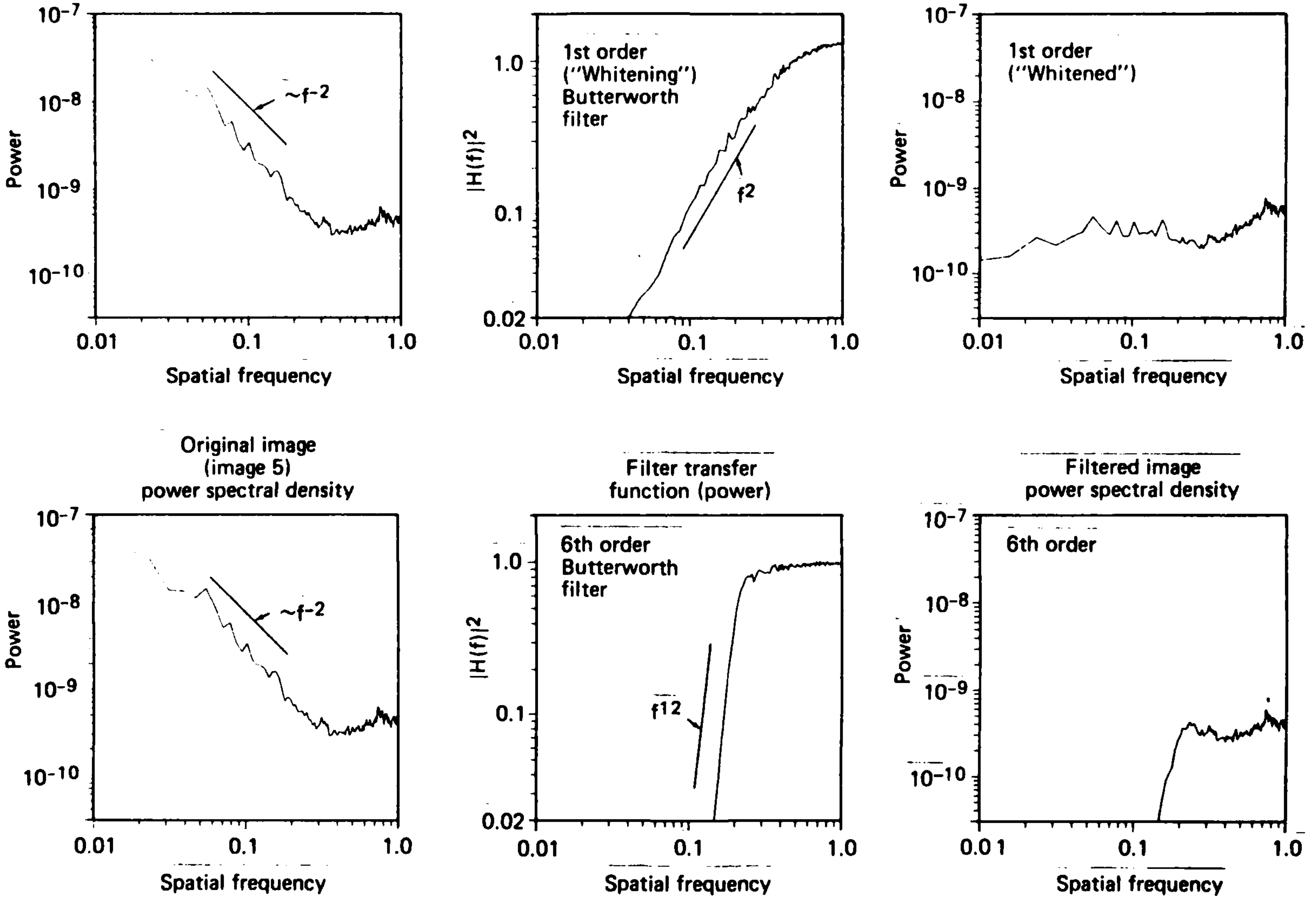
Model Development Summary

- The presence of FLIR internal noise is the limiting factor in lowering the required target irradiance for detection.
- A processing configuration using a matched filter should perform slightly better than one using a rectangular high-pass filter.

Signal Processing Model Performance Evaluation

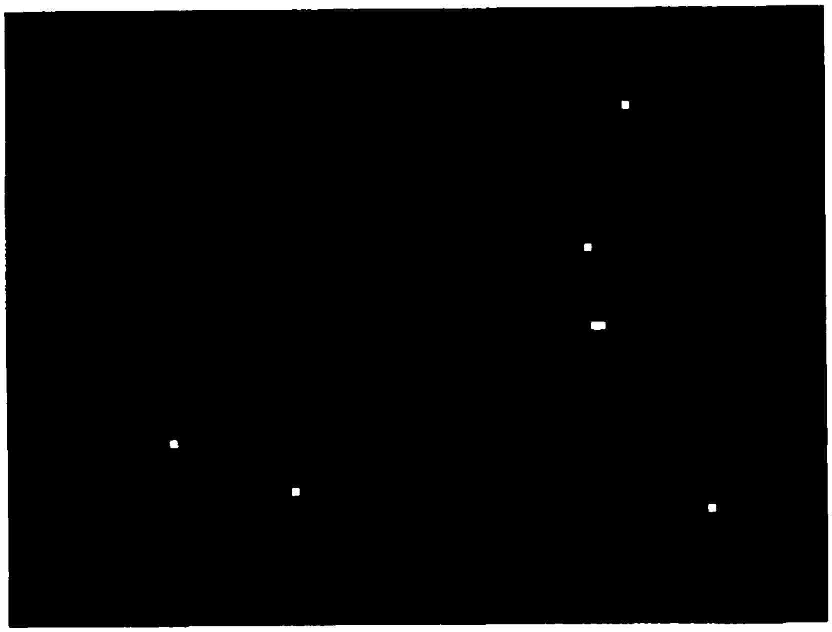
- Matched Filter (1st order Butterworth) Performance
- Rectangular Filter (6th order Butterworth) Performance

DIGITAL FILTER CHARACTERISTICS

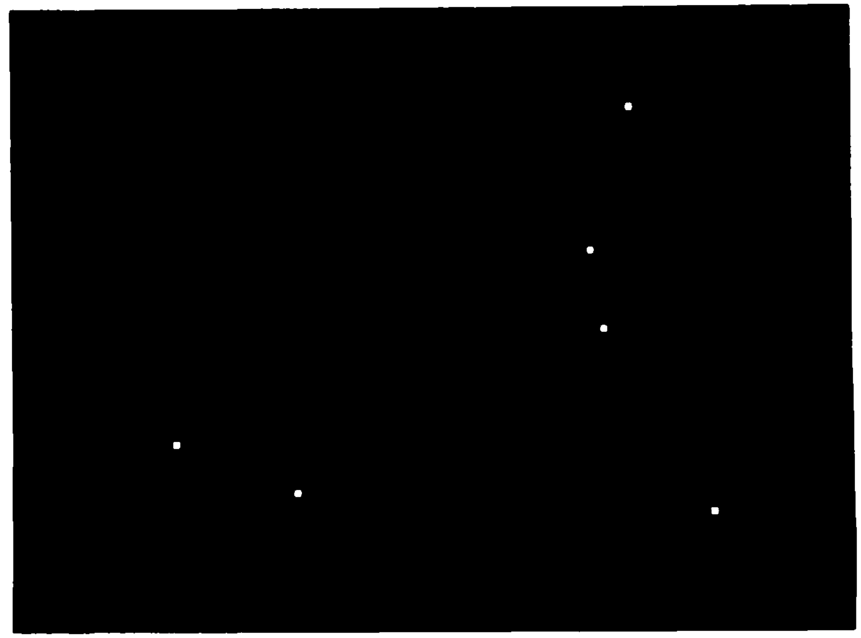


Power units are: $(W/cm^2/sr)^2/cyc/mrad$
Spatial frequency units are: cyc/mrad

IMAGE PROCESSING COMPARISON



CONVOLVED IMAGE



FILTERED IMAGE

Infrared Cloud Backgrounds and Sensor Performance

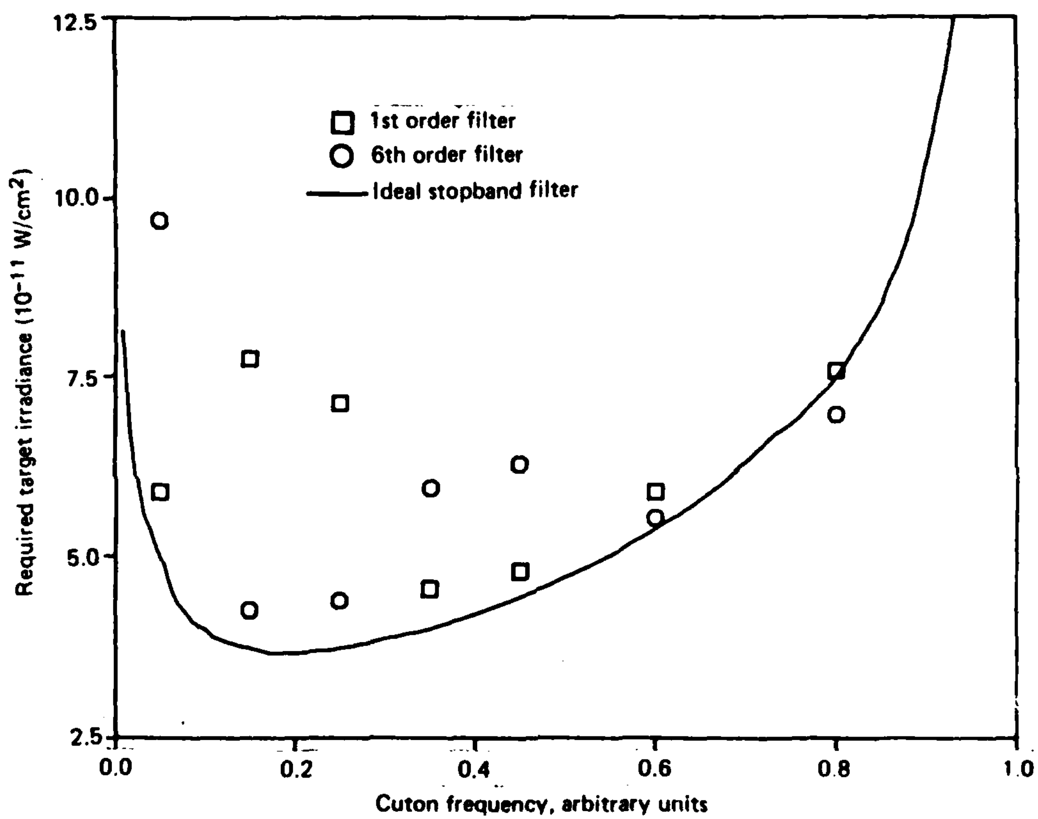
Filter Performance Assuming an Output SNR of 50

$E_{t,req}$ (10^{-11} W/cm^2), SNR = 50

Image	1st order	6th order
I01	5.09	4.27
I05	4.84	4.26
I06	7.36	8.05
I08	15.97	11.66
I09	5.26	4.81
Average	7.70	6.61

Average of Ideal Matched Filter Case, Same Images	5.29
Average of Ideal Bandpass Filter Case, Same Images	5.48

FILTER PERFORMANCE AT VARYING CUTON FREQUENCIES



Model Evaluation Summary

- Real filters of the appropriate orders can serve as reasonable approximations to their ideal counterparts.

- When real filters are used in a processing configuration, sharper cuton filters have improved target enhancement properties over matched filters.

Summary

- A database of infrared cloud/sky/terrain images has been established and characterization of these images effected.
- Simple bandpass filters have been applied to images and evaluated.
- This evaluation has provided useful information about:
  - Simple filter characteristics;
  - Applicability of such filters to our target detection problem;
  - Useability of our data;
  - Sensor sensitivity requirements.

INFRARED BACKGROUND PROCESSING INVESTIGATION

PLANS FOR CY 1984

OBJECTIVES:

- COMPLETE INVESTIGATION OF AVAILABLE SCENES USING DIGITAL BANDPASS FILTERING TECHNIQUES
  - DETERMINE USABLE SENSITIVITY VERSUS SCENE TYPE
  - SELECT FILTERS FOR FURTHER EVALUATION
  - ISSUE REPORT
- EXPAND IMAGE DATA BASE
  - NAVY IR BACKGROUND MEASUREMENTS AND ANALYSIS PROGRAM (NRL)
- INVESTIGATE TIME DOMAIN PULSE–DISCRIMINATION TECHNIQUES

THE NAVY BACKGROUND MEASUREMENT AND ANALYSIS PROGRAM (BMAP)--FY 1984

Bernard V. Kessler
Naval Surface Weapons Center

"The Navy Background Measurement and Analysis Program (BMAP); FY84"

Bernard V. Kessler, NSWC/R42

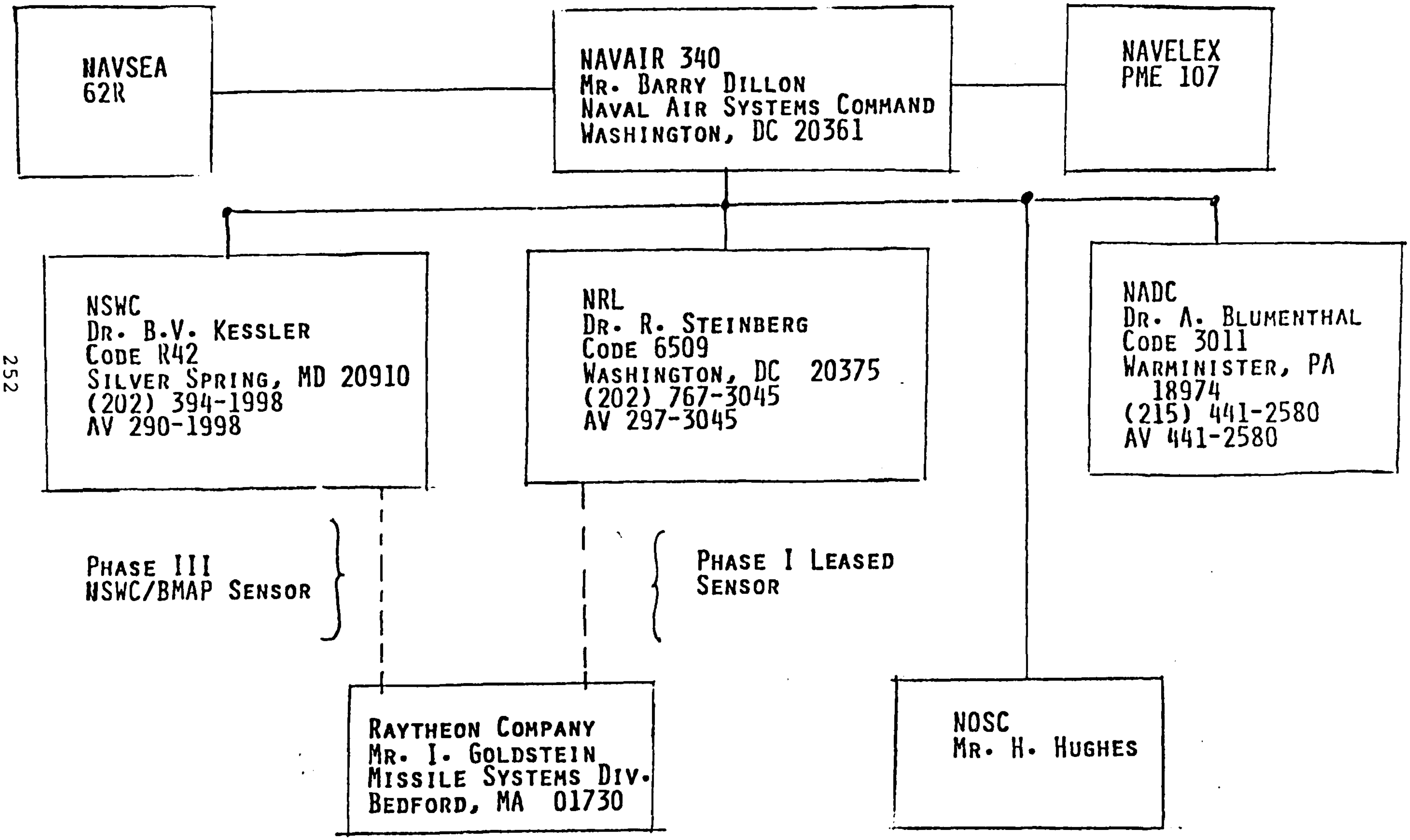
AT

"The Second Tri-Service Cloud Modeling Workshop"/DARPA

26-28 JUNE 1984

NAVAL SURFACE WEAPONS CENTER
White Oak, Silver Spring, Maryland

BMAP ORGANIZATION DIRECTORY

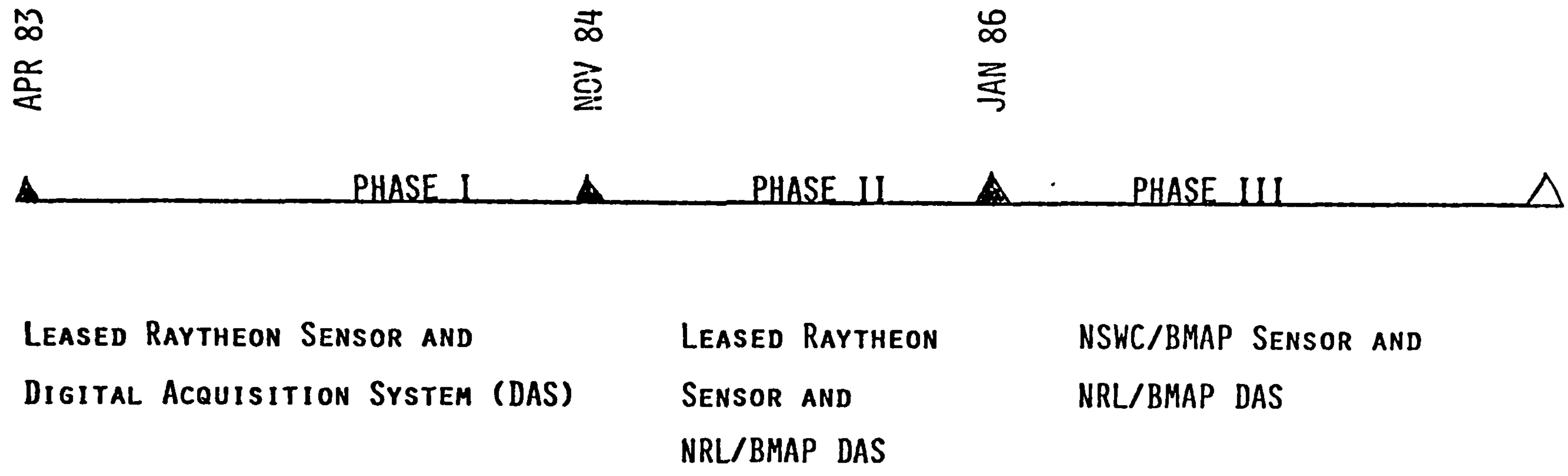


DESIGN ISSUES

- Optimal Pixel Size
- Multicolor Discrimination
- Temporal Discrimination
- Spatial Discrimination
- Spectral Waveband Discrimination
- Polarization Discrimination

<u>BMAP NAVY LABORATORY TASKS</u>

- o NAVAL RESEARCH LABORATORY (NRL)
  - LEAD LABORATORY FOR THE IR BACKGROUND MEASUREMENTS ANALYSIS AND TEST PLANS AND OVERALL TECHNICAL INTEGRITY OF THE PROGRAM
  - AIRBORNE (P-3) SYSTEM INTEGRATION
  - RESPONSIBILITY FOR THE CURRENT RAYTHEON (LEASED) SENSOR CONTRACT
- o NAVAL SURFACE WEAPONS CENTER (NSWC)
  - LEAD LABORATORY FOR INSURING THAT THE SHIPBOARD IR BACKGROUND MEASUREMENTS ARE MET
  - NSWC WILL PREPARE AND CONDUCT THE SHIPBOARD IR BACKGROUND MEASUREMENTS ANALYSIS AND TEST PLANS
  - PRIME RESPONSIBILITY FOR THE NSWC/BMAP SENSOR PROCUREMENT USING (NSWC) CAPITALIZATION FUNDS
- o NAVAL AIR DEVELOPMENT CENTER (NADC)
  - LEAD LABORATORY FOR INSURING THAT AIRBORNE IR BACKGROUND MEASUREMENTS TECHNICAL REQUIREMENTS ARE MET
  - NADC WILL PREPARE AND CONDUCT THE AIRBORNE PORTION OF THE IR BACKGROUND MEASUREMENT ANALYSIS AND TEST PLAN
- o NAVAL OCEAN SYSTEMS COMMAND (NOSC)
  - NOSC WILL PROVIDE E-O METEOROLOGICAL SUPPORT FOR THE IR BACKGROUND MEASUREMENTS ANALYSIS AND TEST PLANS AND METEOROLOGICAL AIRCRAFT SUPPORT AS DEEMED NECESSARY.


APR 83
NOV 84
JAN 86
PHASE I
PHASE II
PHASE III
LEASED RAYTHEON SENSOR AND
DIGITAL ACQUISITION SYSTEM (DAS)
LEASED RAYTHEON
SENSOR AND
NRL/BMAP DAS
NSWC/BMAP SENSOR AND
NRL/BMAP DAS

BMAP PHASE I

RAYTHEON COMPANY LEASED SENSOR

AND

DATA ACQUISITION SYSTEM (DAS)

PHASE I TEST SYSTEM CHARACTERISTICS

Scanner	
Collecting Area (3.9-4.8μ) (8-11)	80 cm^2
Optical Transmission (3.9-4.87)	85%
Optical Transmission (8-11)	80%
Detector Collecting Efficiency (3.9-4.8μ) (8-11)	80%
Total Optical Efficiency (3.9-4.8μ)	68%
Total Optical Efficiency (8-11)	64%
Detector Area (3.9-4.8μ) (8-11)	2.58×10^{-5} cm^2 (2 mils)
Detector D^*_{AV} (1 Hz - 1 kHz F) (3.9-4.8μ)	2×10^{11} cm $Hz^{1/2}$
Detector D^*_{AV} (1 Hz-1 kHz F) (7.6-11.3μ)	1.5×10^{10} cm $Hz^{1/2}$/W
Electronic Bandwidth (3.9-4.8μ) (7.6-11.3μ)	0.0 Hz - 1 kHz 0.5 Hz - 1 kHz
Number of channels single color	16
2 color (per color)	8
Elevation F.O.V.	5.33 mr or 0.31 deg
Azimuth F.O.V.	49 mr or 2.81 deg
Instantaneous F.O.V.	0.33 x 0.33 mr
NEI 3.9 - 4.8μ	1.5×10^{-14} watts/cm^2
NEI 7.6 - 11.6μ	2×10^{-13} watts/cm^2
Scanning frequency	2 scans per second
Scanning speed during data acquisition	36°/sec

TABLE 1 (Cont.)

Detector element dwell time	520 μsec
Azimuth position resolution	0.1 mr
Mirror shaft angle encoder	16 bits
Total incremental count	512
Snap Shot	
Duration time for acquisition	80 msec
Memory words/bank	8192
Memory word depth used	12 bits
Analog to digital converter	12 bits
Numer of inputs	16
Analog to digital factor	2.441 mv/#
Number of frames per start command	2,4,5,10 or continuous
Data Formatter	
Word length	8 bits
Words per record	17416
Program execution	0.375 sec
Digital Tape Transport	
Tape speed	75 in/sec
Tracks	9
Tape tensioning	mechanical
can be used airborne	

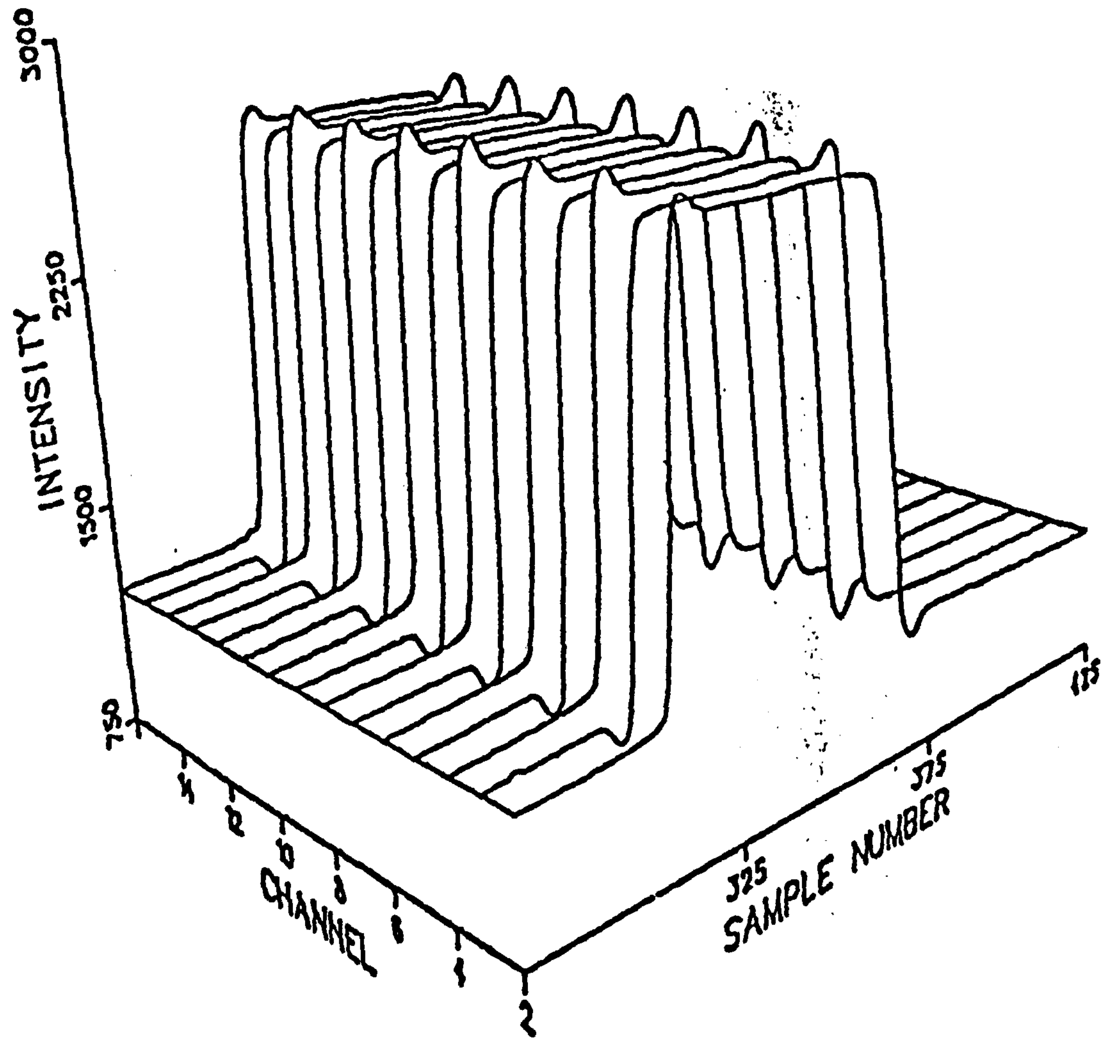
NRL FY84 BMAP ACTIVITIES
RESISTIVE COUPLING ANALYSIS

- BAR TARGET SCANS WERE OBTAINED TO ASSESS RAYTHEON SENSOR SENSITIVITY AND TRANSIENT RESPONSE
  - UNDESIRED ARTIFACTS APPEARED UNEXPECTEDLY IN THE DATA
- THEORETICAL MODEL WAS DEVELOPED
  - ARTIFACTS CAUSED BY SMALL SPURIOUS RESISTANCE IN FOCAL PLANE GROUND CONNECTIONS

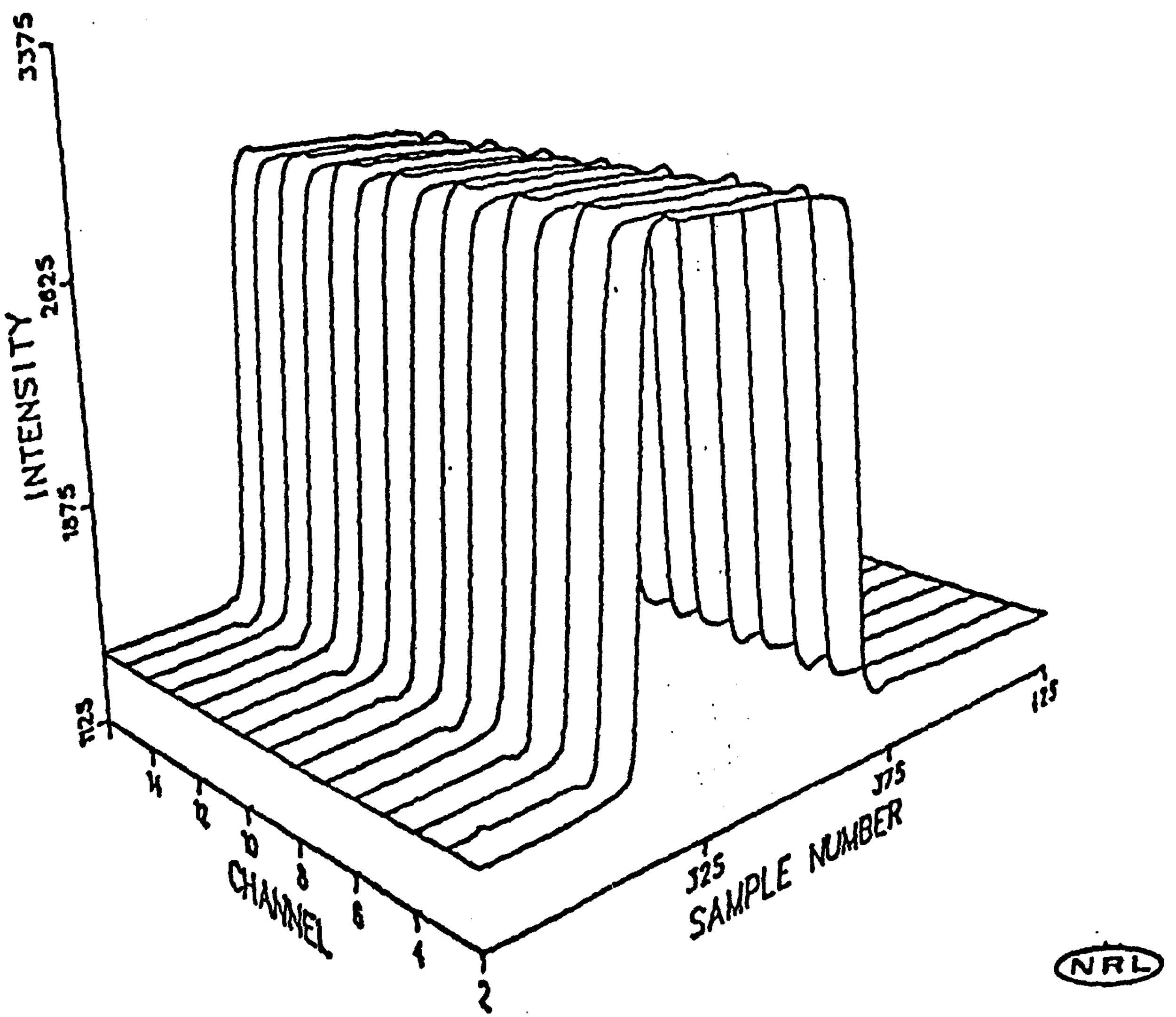
- DATA CORRECTION EQUATION HAS BEEN DERIVED AND VALIDATED
  - CORRECTION ACHIEVED WITHOUT SMOOTHING OR NEI DEGRADATION

NRL

LONG-WAVE BAR TARGET DATA DISPLAYING SPATIAL ARTIFACTS



CORRECTED LWIR BAR TARGET DATA



PERFORMANCE SUMMARY
RESISTIVE COUPLING CORRECTION

- ARRAY-AVERAGE ARTIFACT AMPLITUDE
  (EXPRESSED AS PERCENT OF BAR TARGET AMPLITUDE)

	BEFORE CORRECTION	AFTER CORRECTION
1-BAR DATA	5.6%	0.55%
6-BAR DATA	5.6%	0.70%

NRL

NRL FY84 BMAP ACTIVITIES

SAMPLE ERROR DETECTION/CORRECTION

- LAB & FIELD DATA SHOW LARGE NUMBERS OF DATA ERRORS ORIGINATING IN RAYTHEON DIGITAL DATA ACQUISITION SYSTEM (RAY/DAS)

- TWO SIMULTANEOUS APPROACHES TAKEN
  - HARDWARE FIX
  - SOFTWARE FIX
    SAMPLE FACTOR 3.5 SAMPLES/DWELL MAKES THE DATA ABOUT 2-FOLD REDUNDANT

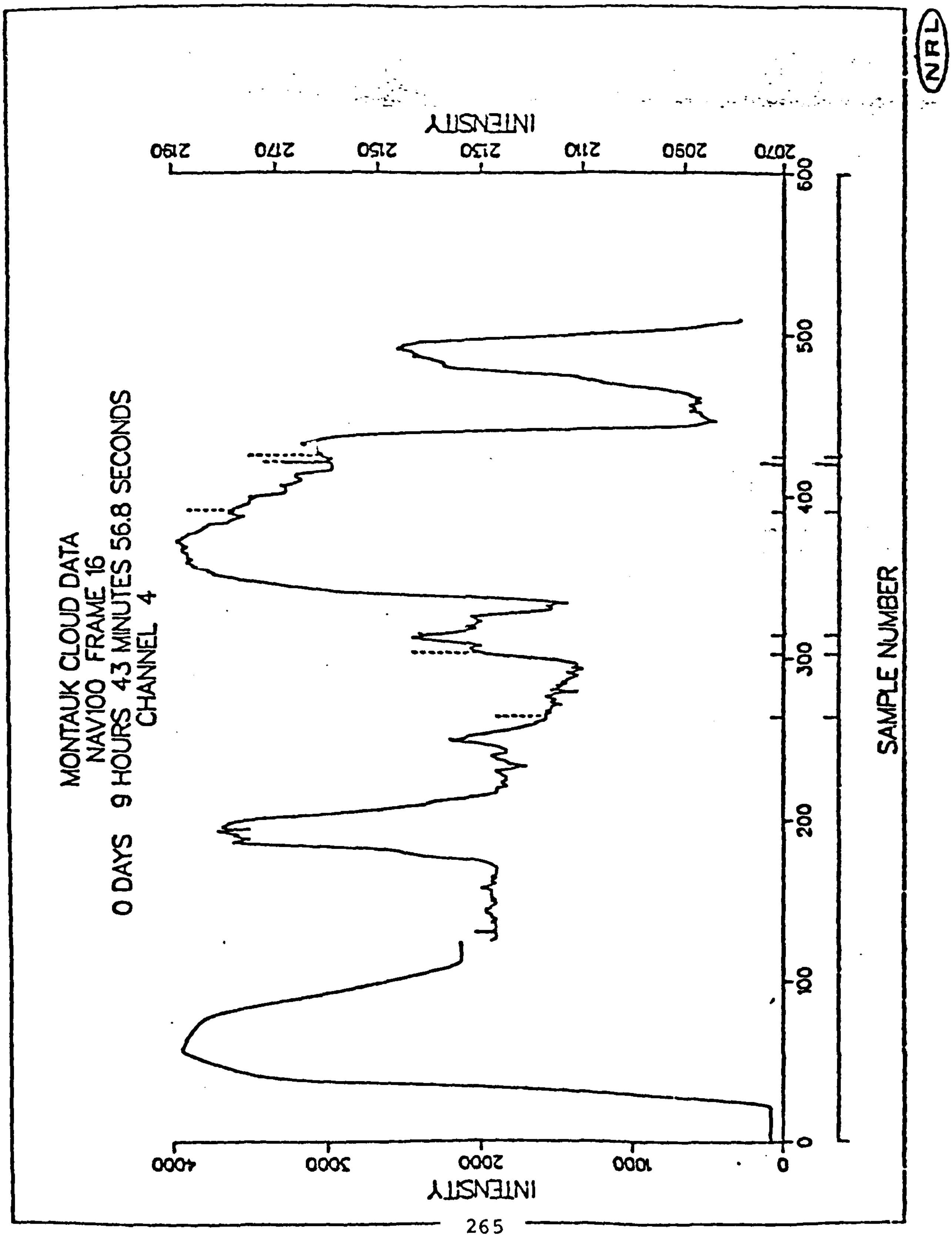
- RESULTS
  - HARDWARE FIX IN PLACE (RAYTHEON)
  - HIGHLY ACCURATE SOFTWARE ERROR DETECTION

NRL

A SYSTEM FOR CORRECTING SAMPLE ERRORS IN IR SCANNER DATA

- PRIOR ART
- SYSTEM POINT-RESPONSE
- ERROR DETECTION USING POINT-RESPONSE CRITERIA
- VALIDATION
  - SYNTHETICALLY DAMAGED DATA
  - LABORATORY MEASUREMENTS
  - FIELD MEASUREMENTS

NRL



MONTAUK CLOUD DATA
NAV100 FRAME 16
0 DAYS 9 HOURS 43 MINUTES 56.8 SECONDS
CHANNEL 4
INTENSITY
INTENSITY
SAMPLE NUMBER
NRL

NRL FY84 BMAP ACTIVITIES

AIRCRAFT CLOSED COVER/EMI TESTS

- OBJECTIVE
  - ASSESS RAYTHEON SENSOR/DATA RECORDER PERFORMANCE IN P-3 ENVIRONMENT
- CONCERNS
  - EMI FROM RADAR & RADIO
  - GROUND LOOPS
  - MICROPHONICS
- APPROACH
  - NRL P-3 FLOWN TO HANSCOM FIELD, DEC 83
  - CLOSED COVER NOISE MEASUREMENTS OBTAINED UNDER VARIOUS OPERATING CONDITIONS

- RESULTS
  - P-3 RADAR, RADIOS, POWER, VIBRATION, PRODUCED NO MEASURABLE EFFECT ON SENSOR NOISE LEVEL

NRL

SENSOR STABILIZATION MOUNT

- Custom designed for Raytheon sensor on P-3 platform
  - Readily adaptable to other scanners and platforms
- LOS stabilization: better than 100 microradians (rms) in smooth flight
- Joystick-controlled steering capability

  $\pm 15^{\circ}$ (min) in elevation

  $\pm 90^{\circ}$ in azimuth
- Physical specifications (including sensor)
  - 5'H x 3'W x 3'D
  - 300 lb. weight
  - power: 900 watt (start-up)

    400 watt (continuous)

NRL

NRL FY84 BMAP ACTIVITIES
AIRCRAFT INTEGRATION

- Frame for side-looking IR window
  - Uses existing NRL ZnSe WINDOW
  - Design, fabrication, P-3 installation
- Integration
  - Tyler platform/Raytheon sensor (payload balancing, acceptance test)
  - Tyler platform/P-3 aircraft (mounting fixtures, flight qual, acceptance)
  - Electronics/aircraft (racks, mounting fixtures, shielded cables)
- Miscellaneous expenses
  - Low pressure N2 bottle; unitron power converter

NRL

NRL BMAP ACTIVITIES

FORWARD-LOOK IR DOME WINDOW FOR P-3 AIRCRAFT

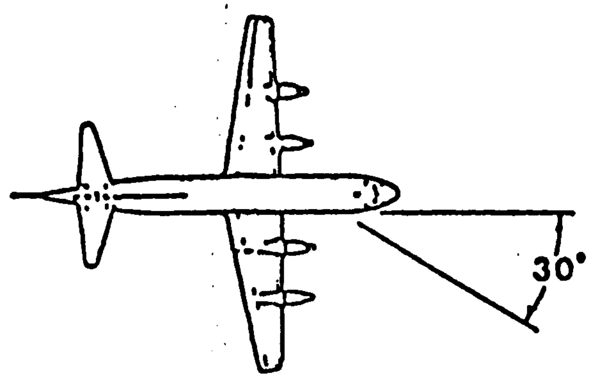
- FORWARD-LOOK NEEDED TO SIMULATE AIR IRST
- IR DOME INSTALLED IN PLACE OF FORWARD OBSERVER'S WINDOW
  - LESS EXPENSIVE & LESS COMPLEX THAN PODS
- STRESS ANALYSIS & ENGINEERING DRAWINGS BEING DEVELOPED

- FLIGHT QUAL. ISSUES BEING ADDRESSED IN FY84

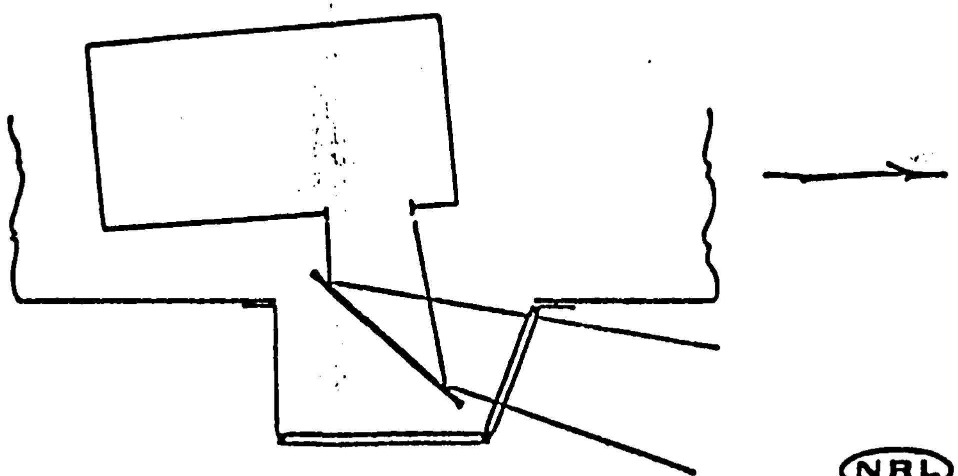
NRL

FORWARD-LOOKING DOME WINDOW FOR P-3 AIRCRAFT

- FIELD-OF-REGARD
  30° (AZIMUTH)
  ±10° (ELEVATION)



- ANGLED MIRROR
  HARD-MOUNTED
  TO SENSOR
  PROVIDES
  FORWARD LOOK



NRL

BMAP QUICK-LOOK ANALYSIS (QLA)

- ON-SITE DATA VERIFICATION
- NECESSITATED BY
  - FLIGHT COSTS
  - LOCAL METEOROLOGICAL CONDITIONS
- EXAMINATION OF DATA
  - DIGITAL IR DATA
  - ANCILLARY DATA

QLA OBJECTIVES

- VERIFY SENSOR SYSTEM HEALTH
  - DETECTORS
  - A/Ds
  - DIGITAL RECORDER
  - IRIG TIME GENERATOR
  - BIT ERROR RATE
- ORGANIZE/COMPLETE FLIGHT TEST DATA
- DATA SCREENING
- PROGRESS VERSUS FLIGHT OBJECTIVES

QLA TOOLS

- TAPE UTILITIES
  - TAPE CATALOG
  - TAPE SEARCH
  - DATA READ
- BIT ERROR CORRECTION
  - MULTIPLE SAMPLE ERRORS
  - THRESHOLD AND TREND ANALYSIS
  - LINEAR INTERPOLATION CORRECTION
- CARPET PLOT
  - VISUAL INSPECTION OF DATA
  - EXAMINE FOR UNCORRECTED ERRORS
  - RECORD FOR QLA REPORT

QLA TOOLS (CONTINUED)

NADC

- GAIN AND OFFSET CALIBRATION
  - USING EXTERNAL BLACK BODIES
  - CALIBRATION CHECK
- HISTOGRAM/STATISTIC CALCULATION
  - DETECTOR NOISE
  - A/D PROBLEMS
- POWER SPECTRAL DENSITY
  - IDENTIFY INTERFERENCE PROBLEMS
  - SYSTEM MTF
  - DATA QUALITY (HIGH FREQUENCY CONTENT)

QLA SOFTWARE STATUS

- SOFTWARE COMPLETE
- APPLICABLE FOR GROUND TEST QLA
- READY FOR FIELD TEST EVALUATION
  - BEDFORD TEST - JUNE 1984

QLA HARDWARE

- HEWLETT PACKARD 9835A DESKTOP COMPUTER
  - 180 K BYTES RAM
  - PLOTTER INSTRUCTION SET
  - CASSETTE TAPE UNIT
  - DIGITAL TAPE INTERFACE
- DYLON DIGITAL TAPE SYSTEM
- HEWLETT PACKARD DIGITAL PLOTTER
- OKIDATA PRINTER

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METRICS

- CHARACTERIZE CLUTTER
- COMPARE SIGNAL PROCESSOR PERFORMANCE
- COMPARE CLUTTER IN TWO SPECTRAL BANDS

NADC

IRST Operating Area of Intrest	Important Cloud Types	Measurement Location (Preferred Order)	Measurement Time
GIUK Gap	Cirrus, CU & SC cells, multilayer cyclonic clouds	Gulf of Alaska from Anchorage or Seattle	February
		Davis Straits Newfoundland	January
Mediterranean	Cirrus, Stratus, SC	Atlantic Ocean off Jacksonville	Spring
		Great Lakes	Summer
Arabian Sea/ Indian Ocean	Towering CU & CB	Gulf of Mexico	March

NADC

Measurement Category	Uses	Analysis Parameters	Truth Parameters	Measurement Sensors	Geometry
I	Scenes	1st and 2nd order radiance stats, edge gradients	Video, cloud type and height range to cloud solar angle air temperature	IR Vidicon weather radar	Long-range horizontal views scaled to appropriate elevation angles & resolution
II	Radiometric analysis of water clouds and thick cirrus	Reflectivity vs solar and observation angles	As in I plus temp and humid; incident solar and earthshine on the cloud	IR Vidicon radar meteorological	Circular coaltitude paths around CU cells; and above and below cirrus decks before and after sunset
III	Radiometric analysis of thin cirrus	Emittance and reflectance vs transmission and angle	As in II plus cirrus transmissivity	IR Vidicon radar meteorological	Straight path below the cirrus viewing the moon through the clouds
IV	Physical analysis	Cloud surface texture; LWC inhomogeneity; edge profiles	As in I plus temp and humid profiles; aircraft flight parameters	IR lidar Knollenberg Vidicon radar	Several passes over and through the cloud in different directions

BMAP MONTAUK MEASUREMENTS SUMMARY

A. HIRSCHMAN

OBJECTIVE

TO COLLECT HIGH SENSITIVITY, HIGH RESOLUTION, HIGH DYNAMIC RANGE ABSOLUTE RADIOMETRIC SURFACE BASED CLUTTER VIDEO.

ORGANIZATION

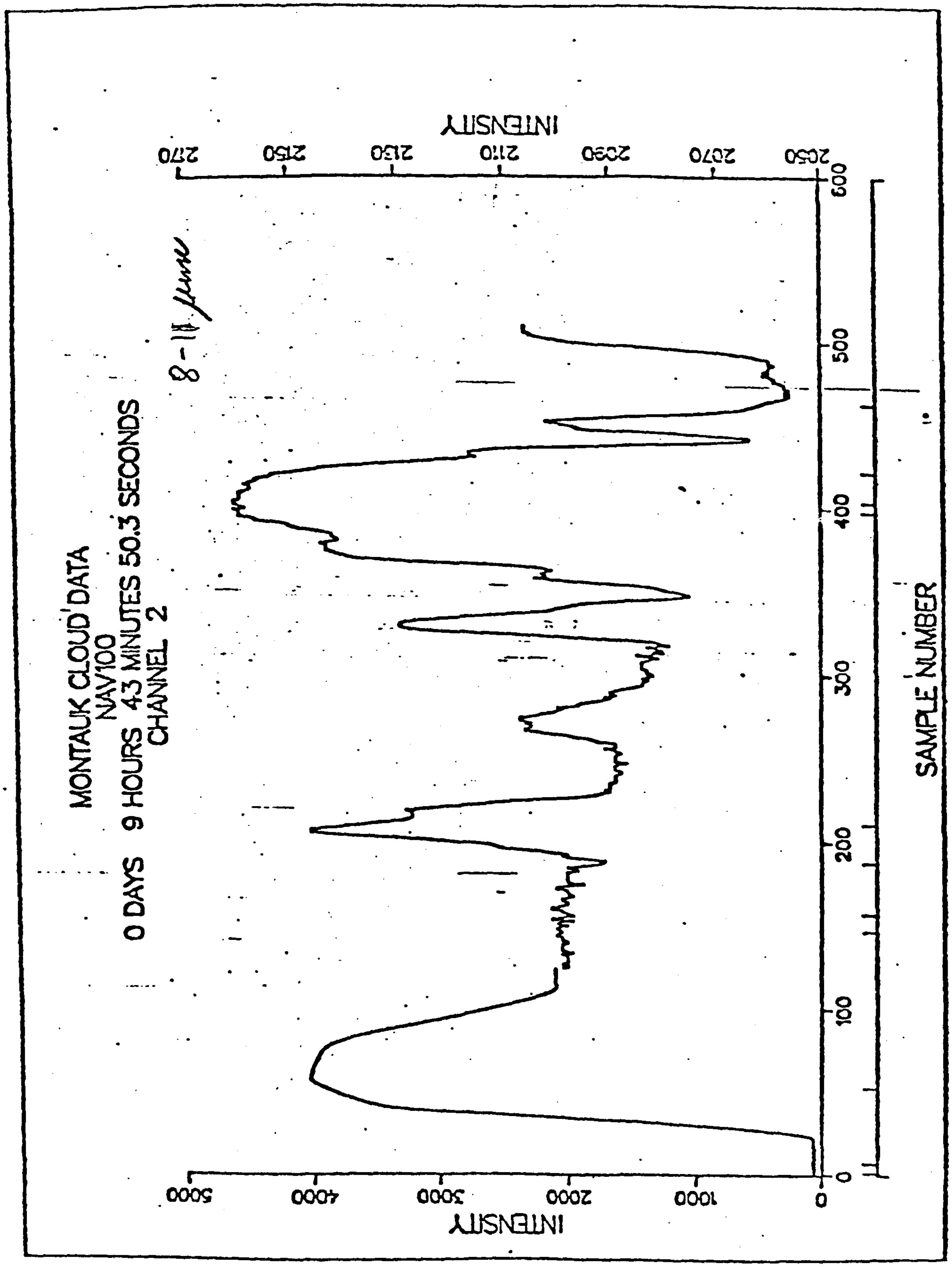
NSWC - DIRECTED, STAFFED, PROVIDED SECONDARY SENSOR, AUX. INSTRUMENTATION
NRL - PARTICIPATED
NADC - OBSERVED
NOSC - EO MET PARTICIPATION
RAYTHEON - PROVIDED PRIMARY SENSOR, DAS, OPERATORS, CALIBRATION
COAST GUARD - HOST

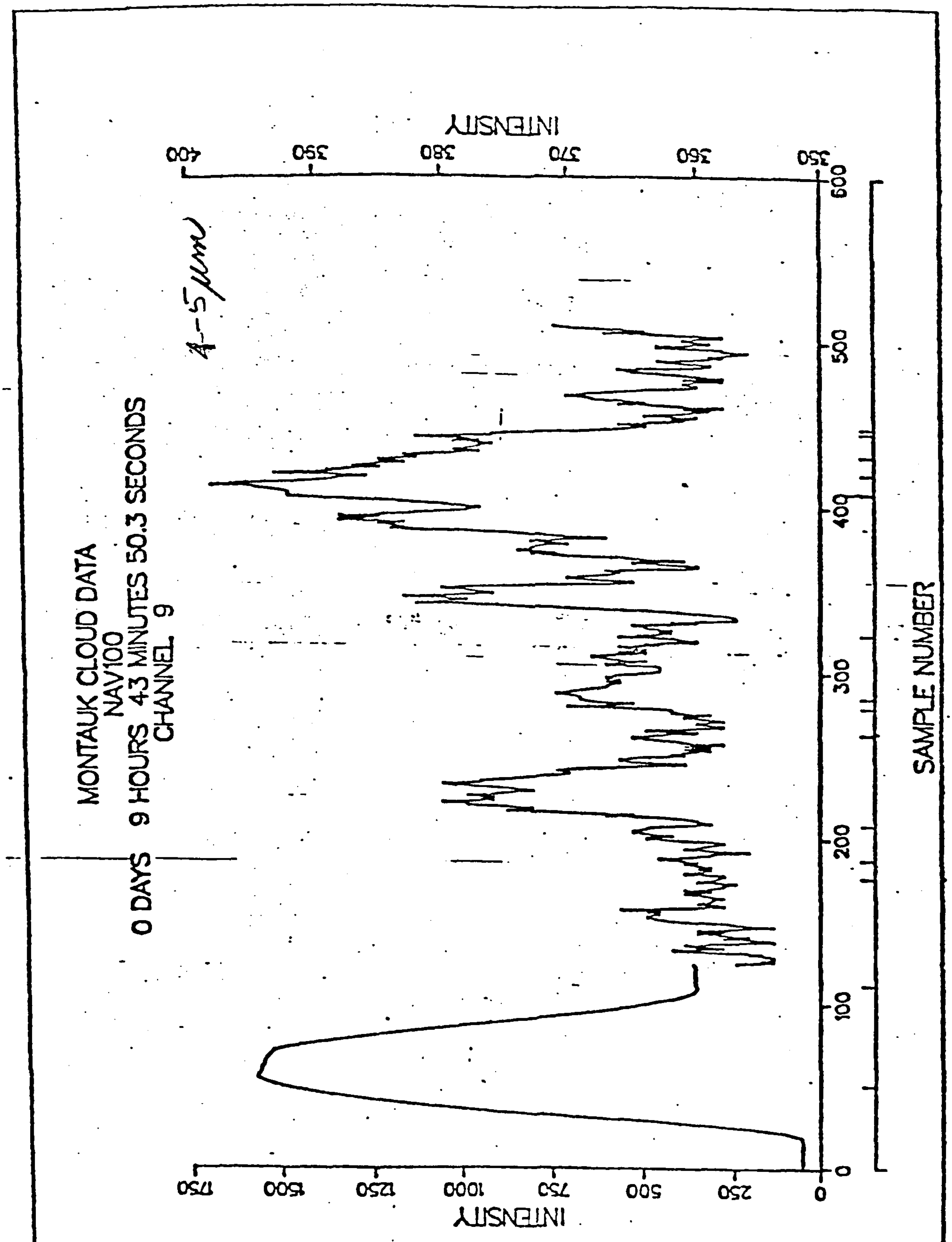
PROBLEMS

DIGITIZER PROBLEM, NO QUICK LOOK CAPABILITY ON SITE, WEIRD WEATHER

RESULTS

A VARIETY OF GOOD DATA OBTAINED WITH EXTENSIVE ANNOTATION. GOOD PROCEDURAL EXPERIENCE. REPORT IN PUBLICATION.

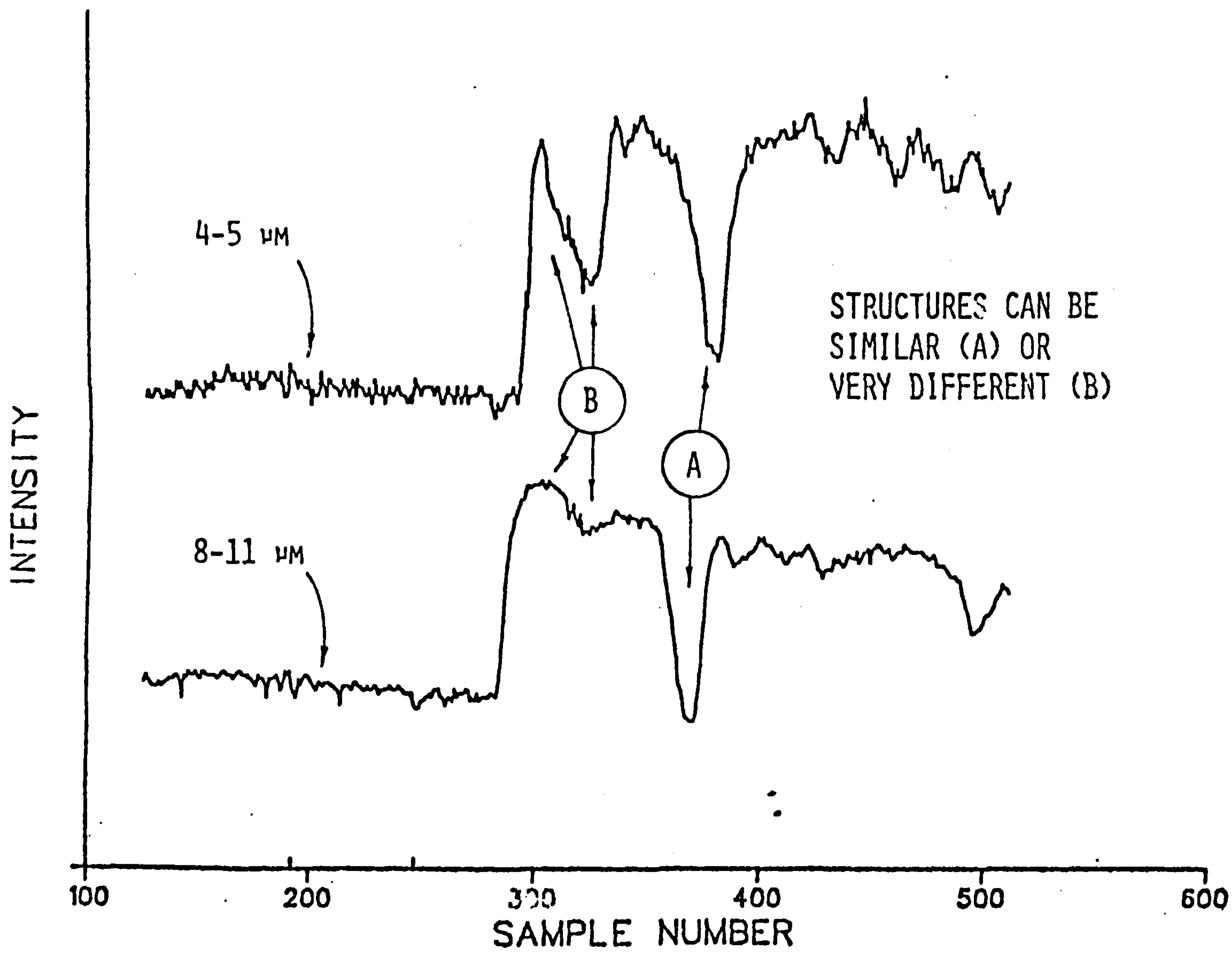

MONTAUK CLOUD DATA
NAV100
0 DAYS 9 HOURS 43 MINUTES 50.3 SECONDS
CHANNEL 2
INTENSITY
0 1000 2000 3000 4000 5000
INTENSITY
2050 2070 2090 2110 2130 2150
SAMPLE NUMBER
0 100 200 300 400 500 600


MONTAUK CLOUD DATA
NAV100
0 DAYS 9 HOURS 43 MINUTES 50.3 SECONDS
CHANNEL 9
4-5 μm
INTENSITY
350 360 370 380 390 400
INTENSITY
0 250 500 750 1000 1250 1500 1750
0 100 200 300 400 500 600
SAMPLE NUMBER

CLOUD EDGE, MID- VS. LONG-WAVE INFRARED

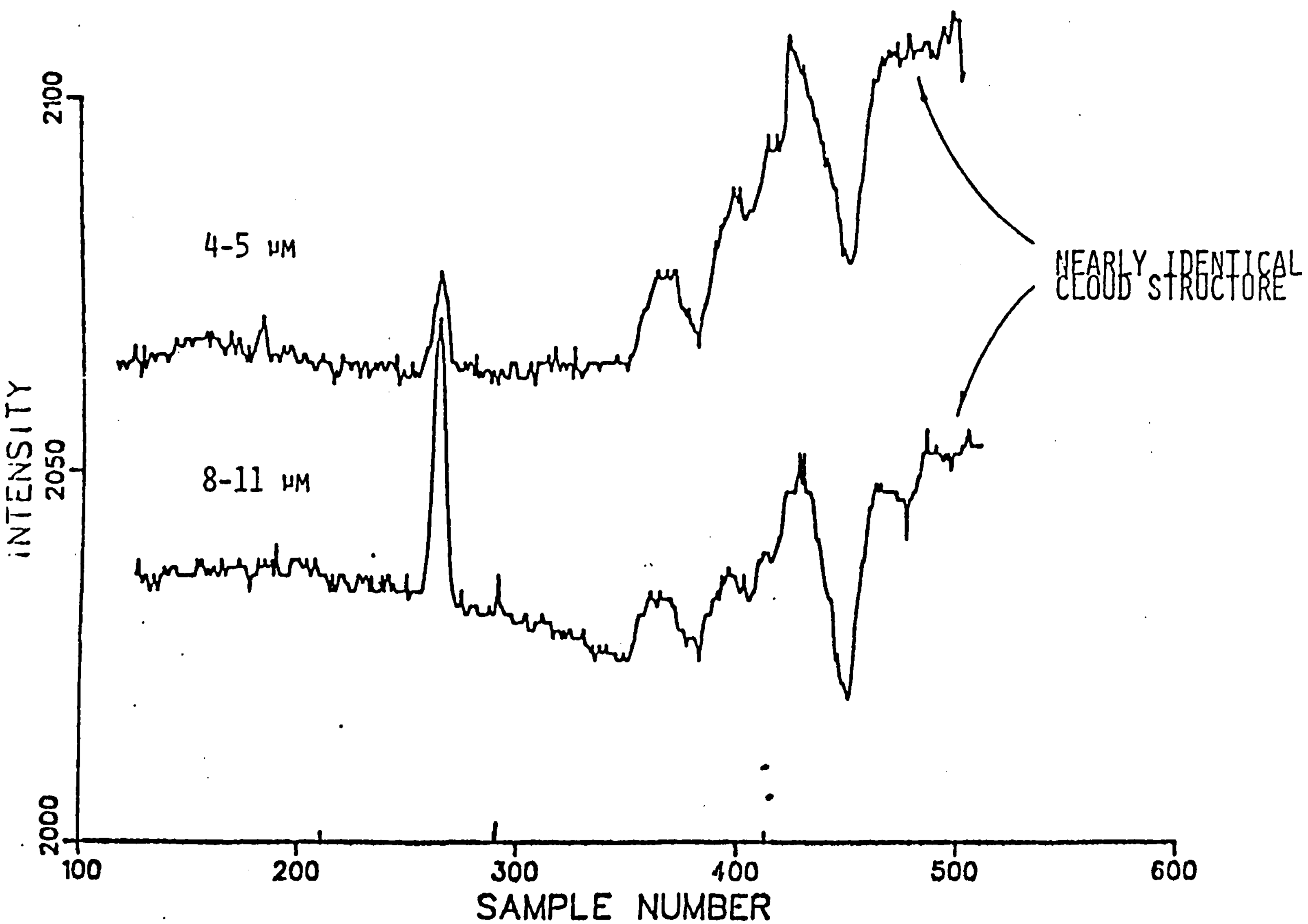
BMAP/MONTAUK POINT

NRL



SMALL AIRCRAFT AT 6 MILES, MID- VS. LONG-WAVE IR

BMAP/MONTAUK POINT



BEDFORD MEASUREMENTS

FIRST TWO WEEKS OF JULY (WINDOW OF OPPORTUNITY)

CLOUD DATA ONLY - NO SEA OR HORIZON

NOSC AIRCRAFT NOT FEASIBLE AT BEDFORD

OPERATION UPGRADES:

- ELIMINATION OF BIT ERROR ARTIFACTS
- QUICKLOOK AVAILABLE (NADC)
- NEW ARRAY
- IMPROVED CALIBRATION PROCEDURE

BARNES RADIOMETER

R8T2

TELESCOPE - 8 INCH CASSEGRAIN, NO WINDOW

DETECTOR - GE IMMERSED THERMISTER

STARING FOV - 8MR X 8 MR

FULL FIELD CHOP TO INTERNAL CAVITY BB REFERENCE SOURCE
INT. REF. SOURCE KEPT AT 40°C FOR THIS OPERATION

FILTERS - 4 FILTERS IN SLIDE, 2 USED FOR THIS OPERATION 3-5 μM, 8-12 μM

TRIPOD - CALIBRATED BEARING AND ELEVATION CIRCLES
IMPROVISED BEARING AND ELEVATION SHAFT ENCODERS USING
LINEAR POTS FOR X-Y SCANS

THIS IS A STARING RADIOMETER. SCANS MADE WITH THIS INSTRUMENT ARE DONE QUASI-STATICALLY BY PANNING IT SLOWLY OVER THE SCENE. IT IS NOT USED TO PRODUCE VIDEO.

BMAP DATA SHEET
MONTAUK POINT LIGHT

DATE/TIME (LOCAL)
8/15/83 0934

SCENE NO.
018

SCENE DESCRIPTION
BROKEN CLOUDS NEAR SOLAR AZIMUTH, VARIED ILLUMINATION

SENSOR DATA

BORESIGHT (TRIPOD) SETTING AZ 126°M EL 6.5°

INTERNAL REF SOURCE TEMP 100°F

TELESCOPE AMBIENT TEMP 74.3°F

DIGITAL TAPE DATA (SCANNER)

REEL NO. NAV 107

BAND	START	STOP
LWIR	15093440	+5 SEC
8/8	3455	+20 SEC
LWIR	3520	+5 SEC
ALT	3532	+20 SEC
SWIR	3558	+10 SEC
LWIR	3611	+10 SEC

ANALOG DATA (SCANNER)

RECORDER VISICORDER

CHANNELS 8/8

COUNTER

ABS. RADIOMETER

RECORDER X - Y

COUNTER ---

DATE/TIME
8/15/83 0934

SCENE NO
018

SCANNER FIELD CALIBR

RANGE TO SOURCE 70'

SOURCE TYPE, TEMP. 12" x 12"

DATA

BAND	START	STOP
SW	15093858	+2.5 SEC
LW	3937	+2.5 SEC
LW COVERED	4047	+2.5 SEC
ALT COVERED	4109	+2.5 SEC

CAMERA RECORDS

HAND HELD - SNAP, ROLL, FRAME ROLL 2

SENSOR MOUNTED - SNAP, TV

METEOROLOGICAL DATA
SURFACE OBSERVATIONS

TEMP. - DRY BULB 66°F

- WET BULB 59°F

WIND DIRECTION N SPEED 10 MPH

BAROMETER

VISIBILITY > 20 MI

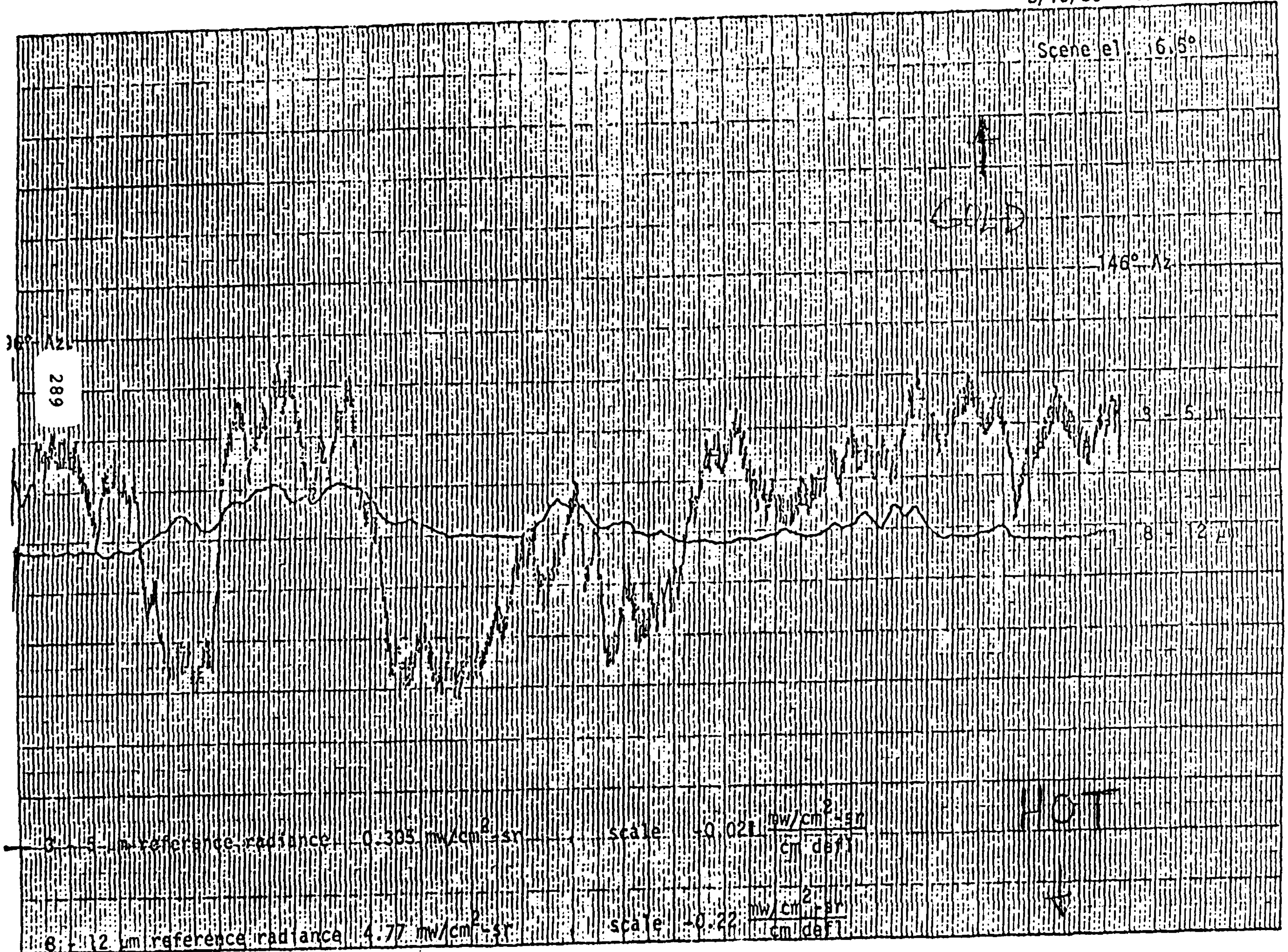
SUN AZ ________ EL ________

AIRCRAFT USED YES NO ✓

EST. RANGE TO CLOUD (BASIS) ----

Scene 18

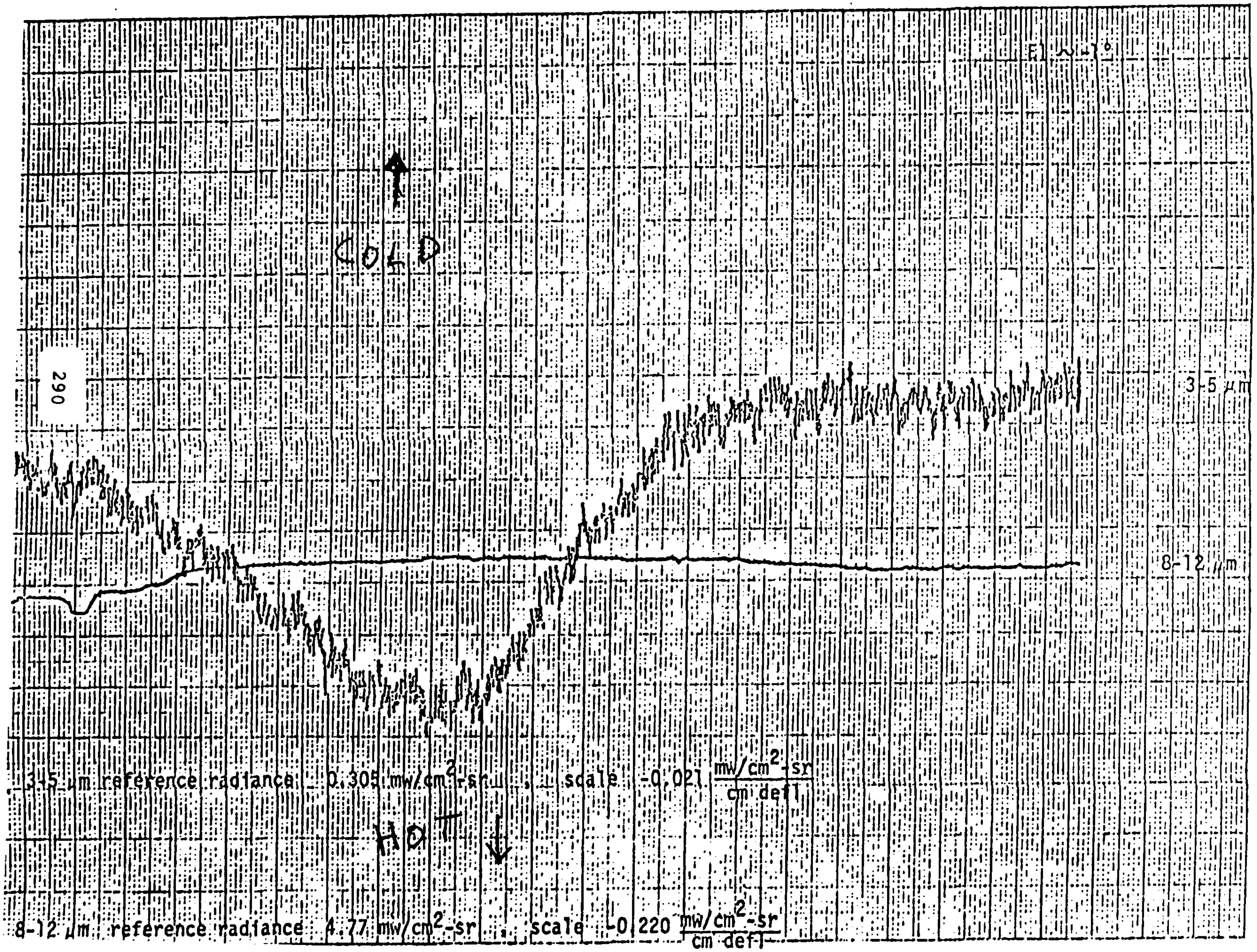
8/15/83 0935 EDT



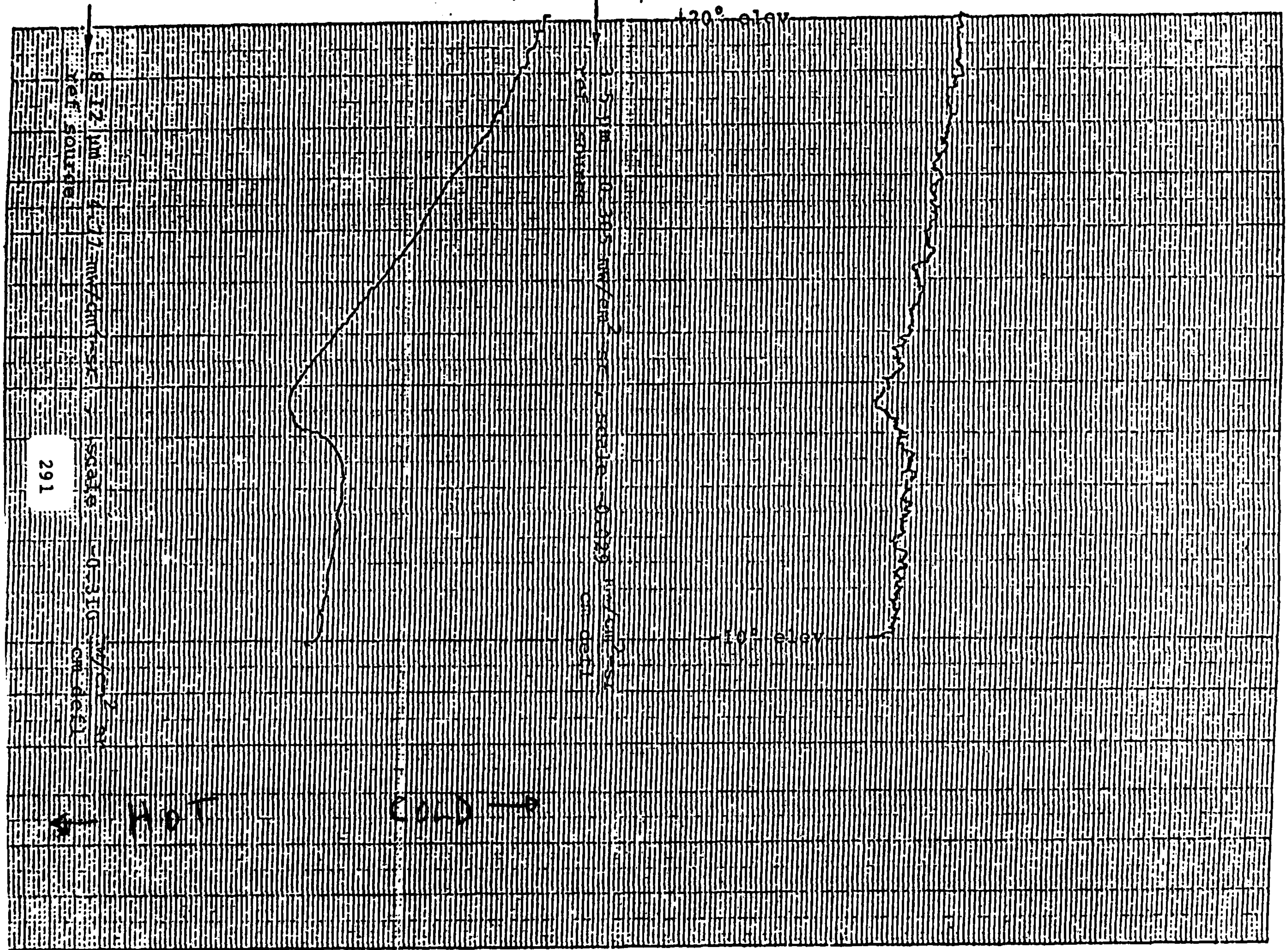
... THROUGH CLOUDS AT 6.5° EL.

Scene 19

8/15/83 0950 EDT



Special Scene #1
8/16/83 1525 EDT



BARNES RADIOM. VERTICAL SCANS OF CLEAR SKY AT 162° AZ

CLOUD MODELING - AN INTEGRAL PART OF BMAP MEASUREMENTS

MODEL PREDICTS BACKGROUND CLOUD CLUTTER RADIANCE AND TEXTURE

1. MODEL INDICATES CLOUDS TO BE MEASURED; AN AID IN SITE SELECTION

2. MODEL DEFINES SUPPORTING EO MET DATA BASE REQUIRED TO RECOVER INHERENT CLOUD STRUCTURE

3. MODEL RESULTS COMPARED TO MEASURED DATA
   - REFINE MODEL
   - IMPROVE MEASUREMENT PROCESS

4. VALIDATED MODEL CAN GENERATE SYNTHETIC CLOUD CLUTTER DATA BASE

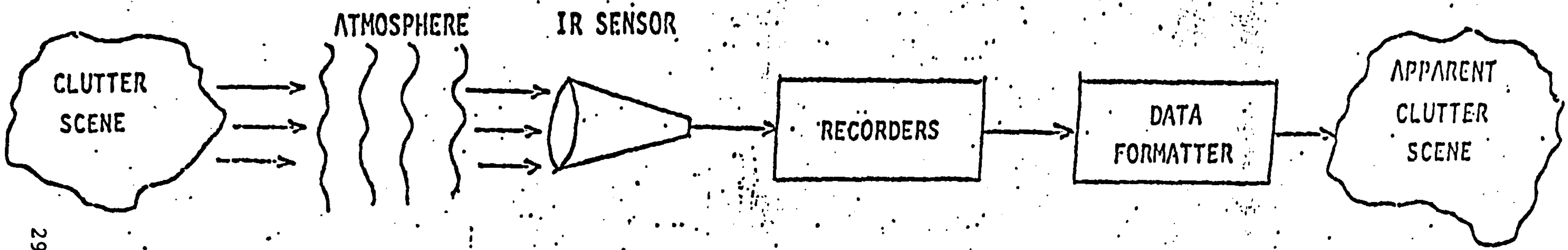
5. MODEL/DATA AGREEMENT TELLS US WHEN WE ARE FINISHED; DISCREPANCIES INDICATE FUTURE WORK

RECOVER INHERENT CLOUD CLUTTER

SPYROS K. PETROPOULOS

CLUTTER IS IN THE EYES OF THE BEHOLDER

PERCEIVED CLUTTER $\neq$ INHERENT (TRUE) CLUTTER



TO ARRIVE AT INHERENT (TRUE) CLUTTER SCENE IT IS NECESSARY TO REVERSE CONVOLUTIONS/OTHER OPERATIONS

ATMOSPHERIC EFFECTS $\simeq$ ATTENUATION & NOISE

CONVOLUTIONS/OTHER OPERATIONS BY RECORDERS, DATA FORMATTERS AND NOISE ADDITION MUST BE CONSIDERED

CONVOLUTION BY IR SENSOR MOST IMPORTANT

NSWC

PROGRAM CHAR(ACTERIZATION)

BMAP
MAY 84
SKP
SPYROS K. PETROPOULOS

---DEVELOPED PROGRAM CHAR WHICH, AT THIS TIME, PERFORMS

- POWER SPECTRAL DENSITIES OF AMPLITUDES OF EACH CHANNEL
- AVERAGE OF PSDs OF SEVERAL CHANNELS
- STANDARD DEVIATIONS (S.D.) OF PSDs
- CROSS - PSDs
- AUTOCORRELATION FUNCTION OF EACH CHANNEL
- AVERAGE AND S.D.s OF AUTOCORRELATION FUNCTIONS OF SEVERAL CHANNELS
- CROSS-CORRELATION FUNCTIONS
- PLOTS AND TABLES IN STATIONARY AND EVOLUTIONARY MODES
- ZOOM FEATURES

---MORE CHARACTERIZATION METRICS WILL BE ADDED

BMAP PHASE II

RAYTHEON LEASED SENSOR

AND

NRL/BMAP DAS

NRL FY84 BMAP ACTIVITIES

DATA ACQUISITION SYSTEM DEVELOPMENT

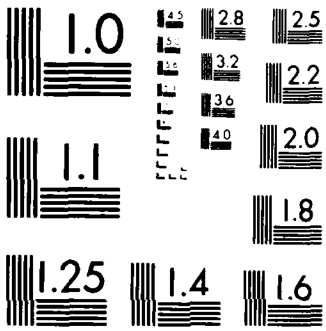
DATA RECORDER	RAYTHEON	NAVY		
WORD DEPTH (BITS/SAMPLES)	12	15		
ELEVATION TOTAL FIELD-OF-VIEW (CHANNELS/WAVEBAND)	8	16		
		SWITCH SELECTABLE		
AZIMUTH SCAN (DEGREES)	2.2°	2°	6°	15°
RELATIVE FRAME SIZE	1	2	6	15
FRAME RATE (FRAMES/SEC)	2	15	5	2
RELATIVE DATA COLLECTION EFFICIENCY	1	15		

o NEW DATA RECORDER PROVIDES 15-FOLD INCREASE IN DATA COLLECTION EFFICIENCY OF EXISTING SENSOR

NRL

AD-A152 735 PRESENTATIONS AT THE TRI-SERVICE CLOUD MODELING WORKSHOP (2ND) HELD AT TH..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA E BAUER AUG 84 IDA-M-9-VOL-1 4/7

UNCLASSIFIED IDA/HQ-84-28971 MDA903-84-C-0031 F/G 4/2 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

BMAP PHASE III

NSWC/BMAP SENSOR

AND

NRL/BMAP DAS

NSWC/BMAP SENSOR

PROCUREMENT TO RAYTHEON COMPANY, 27 JAN 1984
$1.45M NSWC N60921-84-C-0060
DELIVERY JANUARY 1986

ISSUES

- SPECTRAL COLD FILTERS/SPECTRAL WARM FILTERS
- 2 OPTIONAL 8" AFOCAL + EXTERNAL SCANNER
- ORIGINAL MOREPOD CONFIGURATION NOT VIABLE
- 2 FOCAL PLANE ARRAY COMPATIBILITY
- DEWAR DESIGN
- ELEVATION SCANNING IN TWO BARS
- 1 RADIOMETRIC CALIBRATION TECHNIQUE
- GROUND BASED/AIRBORNE COMPATIBILITY

ADVANTAGES OF NSWC NAVY DMAP SENSOR

- 20° WIDE AZIMUTHAL TOTAL FIELD OF VIEW NEEDED FOR ISLAND, SHORELINE, CLOUD BACKGROUNDS

- 5-FRAME/SEC (AT AZ. NTFOV = 6°): BACKGROUND DATA BASE FOR FAST SCAN SYSTEMS
  - CLOUD DYNAMIC INFORMATION
  - FAST MANEUVERING TARGETS
  - ALLOWS SMALLER TRACKING FILE GATES
  - FRAME DIFFERENCING ALGORITHMS EASIER TO RE-REGISTER AND EVALUATE

- FUTURE GROWTH ASSURED BACKGROUND DATA BASE ACQUISITION SUITABLE FOR FPA/TDI PERFORMANCE ASSESSMENT, PREDICTION AND COMPARABILITY
  - 0.125 MR FOV WITH 8" AFOCAL APERTURE:
  - GREATER SENSITIVITY FOR FPA/TDI COMPARABILITY
  - IMPROVED ANGULAR SPATIAL RESOLUTION TO COMPARE WITH FPA/TDI
  - ALLOWS IMPROVED 2-D SPATIAL FILTERING ALGORITHMS

- ELEVATION TFOV (30 MR) ALLOWS SEA/HORIZON LINE/SKY DATA AS WELL AS CLOUD/SKY BOUNDARY IN ONE SINGLE SCAN (COMPARED TO RAYTHEON SENSOR; 5 MR TFOV)

- ALLOWS VALID TARGET DATA ACQUISITION IN IRST SCAN MODE
  - TO TRACK A TARGET WITH 5 MR ELEVATION TFOV (RAYTHEON) RENDERS THE BACKGROUND MOVING AND TARGET VIRTUALLY STATIONARY. IRST OPERATIONAL MODE KEEPS BACKGROUNDS STATIONARY.

	RAYTHEON RENTAL SENSOR	NSWC BMAP NAVY SENSOR & DAS	
WAVEBANDS	4-5 μM AND 8-12 μM	3-5 μM AND 8-12 μM	
IFOV	0.33 MR	0.25 MR (4" APERTURE) 0.125 MR (8" APERTURE)	
CHANNELS/WAVEBAND	16	120	
TOTAL CHANNELS RECORDED	16	240	
ELEVATION TFOV	5 MR	30 MR	
AZIMUTH FOV	2.2°	NARROW AZ. TFOV	WIDE AZ. TFOV
	(15° WITH NAVY DAS)	6°	20°

	CURRENT RAYTHEON	RAYTHEON WITH NAVY DAS		
RELATIVE DATA COLLECTING EFFICIENCY	1	14		100
FRAME RATE	1/SEC		5/SEC	1.5 SEC
			4" APERTURE	8" APERTURE*
SENSITIVITY (NEI) MWIR	2×10^{-14} W/CM^2		2×10^{-14} W/CM^2	0.5×10^{-14} W/CM^2*
LWIR	2×10^{-13} W/CM^2		2×10^{-13} W/CM^2	0.5×10^{-13} W/CM^2*

		RAYTHEON RENTAL SENSOR	NSWC BMAP NAVY SENSOR 4" APERTURE	8" APERTURE
IFOV		0.33 MR	0.25 MR	0.125 MR
SENSITIVITY (NEI)	MWIR	2×10^{-14} W/CM^2	2×10^{-14} W/CM^2	0.7×10^{-14} W/CM^2**
	LWIR	2×10^{-13} W/CM^2	2×10^{-13} W/CM^2	0.7×10^{-13} W/CM^2

*KEEPING SAME VIDEO BANDWIDTH AS FOR 4" APERTURE. 8" APERTURE IS AN AFOCAL FRONT END. E/No. REMAINS UNCHANGED AT F/3. AZIMUTHAL IFOV IS HALVED FOR BOTH AZ. AND EL. IFOV.

**FACTOR OF 2 INCREASE IN BANDWIDTH TO OBTAIN FACTOR OF TWO INCREASE IN AZIMUTHAL SCAN SPATIAL RESOLUTION MADE AVAILABLE THROUGH USE OF AFOCAL 24" FOCAL LENGTH FRONT END OPTICS.

NSWC/BMAP Sensor Design for Performance Growth

MWIR

	IFOV, AZ x EL (MR)		Sensitivity NEI (W/cm^2) (36° /sec scan speed)	
	3 mil detector	1.5 mil detector	3 mil detector	1.5 mil det.
4" aperture	0.25 x 0.25	0.125 x 0.125	1.4×10^{-14}	1.0×10^{-14}
8" focal aperture	0.125 x 0.125	0.063 x 0.063	0.5×10^{-14}	0.35×10^{-14}

4. SENSOR TECHNICAL REQUIREMENTS SUMMARY

TABLE I

4.1 DUAL WINDOW IR OPERATION

DUAL WINDOW IR OPERATION	3-5 μM AND 8-12 μM
IFOV (AZ X EL; MR)	0.25 x 0.25
TFOV (AZ X EL)	$6^\circ \times 1.7^\circ$ (NTFOV) $30^\circ \times 3.4^\circ$ (WTFOV)
ACQUIRE VIDEO DURING BOTH DIRECTIONS	YES
SCAN RATE	$\approx 36^\circ$/SEC
FRAMES/SEC (ONE FRAME IS ONE BACK FORTH SCAN)	3 @ NARROW TFOV 0.3 @ WIDE TFOV
SENSOR TO BE COMPATIBLE WITH STABILIZATION JITTER	< 60 μMRAD
TV VIDICON BORESIGHT MOUNT	YES (SURFACE BASED)
SENSOR WEIGHT	< 60 LBS (AIRBORNE CONFIGURATION)
FPA (TDI) COMPATIBILITY	YES

TABLE I (CONTINUED)

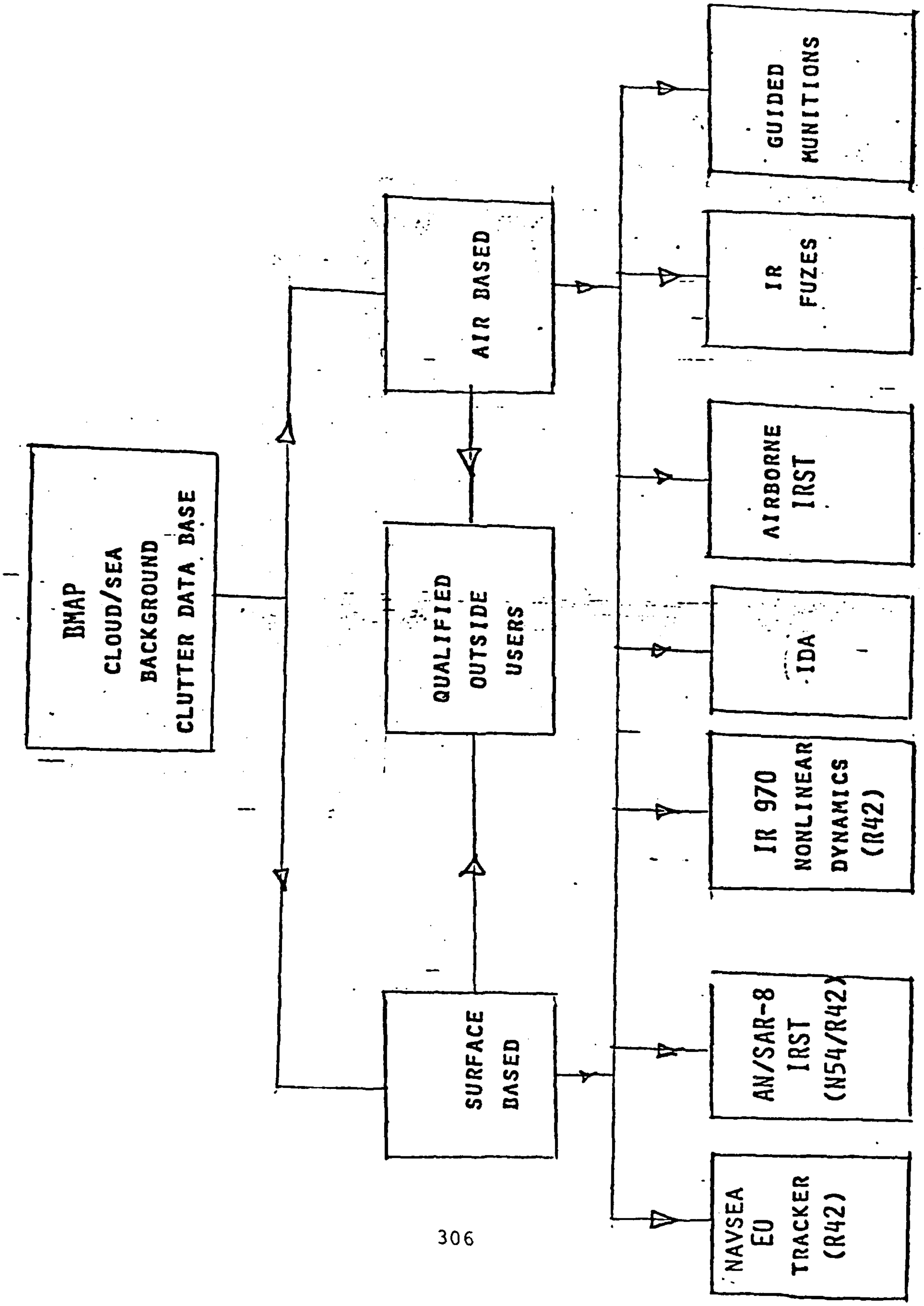
DETECTORS	
NO. DETECTORS/WAVEBAND	120
1/F NOISE SHOULDER	
MWIR (HZ)	≤ 0.5
LWIR (HZ)	≤ 300
NEΔT (PIXEL-TO-PIXEL), NO NEAR ZEROS IN MTF)	$\leq 0.15°C$
NEI (W/CM^2) (72°/SEC SCAN)	
MWIR	$< 2 \times 10^{-14}$
LWIR	$< 2 \times 10^{-13}$
DETECTOR & ELECTRONICS DYNAMIC RANGE	≥ 90 DB
PIXEL REGISTRATION	
SINGLE COLOR	BETTER THAN 0.25 IFOV (SCAN-TO-SCAN)
COLOR-TO-COLOR	SYSTEMATIC CONSTANT OFFSET KNOWN TO WITHIN 0.25 X IFOV
DETECTOR ARRAY GEOMETRY (SUGGESTED)	LINEAR ARRAYS, STAGGERED, CONTIGUOUS
DC RESTORATION, ON OR OFF LINE	YES
SELECTABLE SPECTRAL FILTERS IN 3-5 μM BAND	SWITCHABLE
AZIMUTHAL SHAFT ENCODER	16 BITS (0.1 MR RESOLUTION)

TABLE I. (CONTINUED)

4.2	RADIOMETRIC OPERATION	
	RADIOMETRIC ACCURACY	
	ABSOLUTE	≤ 10%
	REPEATABILITY	≤ 3%
	TEMPERATURE RANGE OF CLOUDS TO BE MEASURED	220°K TO 320°K
	TEMPERATURE RANGE OF TARGETS TO BE MEASURED	270°K TO T.B.D. (PLUMES)
4.3.	ELECTRONICS	
	PREAMPS AND POSTAMPS	
	DYNAMIC RANGE	> 90 DB
	VIDEO PASSBAND	0.0 TO 7500 HZ (3-5 μM)
		0.2 HZ TO 7500 HZ (8-12 μM)
	VIDEO COUPLING	DC AND AC

TABLE I. (CONTINUED)

4.4 MODULAR TELESCOPE DESIGN	
TELESCOPE	
APERTURE	$\geq$ 4-5"
COLD SHIELDING	$\geq$95% COLD SHIELDING EFFECTIVENESS
PHOTONS/MIL^2-SEC x 10^3	$\leq 50 \times 10^8$
MWIR	T.B.D.
LWIR	T.B.D.
4.5 FOCAL PLANE ARRAYS	
3-5μM FOCAL PLANE ARRAY (TDI); TYPICAL CHARACTERISTICS	
AVERAGE BACKGROUND PHOTON (PHOTONS/MIL^2-SEC)	$\lesssim 50 \times 10^8$
FLUX ALLOWED ON FOCAL PLANE (3-5μM)	
TYPICAL FPA (TDI) WELL CAPACITY	10^6 TO 10^7 ELECTRONS
FPA (TDI) SIZE	200 MILS X 200 MILS
FPA (TDI) DYNAMIC RANGE	14 BITS (34 DB)
OPERATIONAL TEMP.	$T \leq 80^\circ K$
DWELL TIME/DETECTOR	200 μ SEC
TYPICAL FPA (TDI) DETECTOR ELEMENT SIZE	1.5 MILS (BLUR CIRCLE SHOULD BE EQUAL OR SLIGHTLY LESS)
SCAN LINEARITY	< 1/10 IFOV/DWELL <u>AND</u> < 1/10 IFOV TOTAL ACCUMULATED ERROR OVER FPA (TDI) FOCAL PLANE AREA


DMAP
CLOUD/SEA
BACKGROUND
CLUTTER DATA BASE
AIR BASED
QUALIFIED
OUTSIDE
USERS
SURFACE
BASED
GUIDED
MUNITIONS
IR
FUZES
AIRBORNE
IRST
IDA
IR 970
NONLINEAR
DYNAMICS
(R42)
AN/SAR-8
IRST
(N54/R42)
NAVSEA
EO
TRACKER
(R42)

PROGRESS

- Completion of dual-band leased sensor by Raytheon
  - New calibration technique
- BMAP Test[1] and Analysis[2] Plans
- Successful correction of resistive coupling defect[3]
- Successful accomplishment of first surface-based measurements at Montauk Point, L. I. NY, Aug 1983[5]
- Effective sample error correction software developed, validated and documented
- Quick Look Analysis (QLA) Software development validation and documentation
- NSWC/BMAP Sensor Procurement awarded Jan 1984 to Raytheon Company, $1.45 M, delivery Jan 1986
- Production of research tapes and dissemination in NATO RSG image transfer CCT format

Tasks to be accomplished yet next year:

- Second Surface Based Measurements, late Summer 1984
- Development and fabrication of NRL/BMAP 240-Channel Data Acquisition System (DAS), Fall 1984
- Modification of leased Raytheon scanner for wide FOV operation (20^o azimuth), Fall 1984
- Absolute calibration of Raytheon sensor
- Development of forward-looking IR dome window for P3
- Development of a passive line-of-sight stabilization for airborne operation, Fall 1984[4]
- Integration of the dome window, stabilization system and Raytheon sensor into P3 (Winter 1984)
- First airborne measurement series, late Fall 1984

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5. A. Hirschman, et al, NSWC/R42, "BMAP Surface-Based Background Measurement Activities at Montauk Pt., N.Y., Aug 1983"

AN EMPIRICAL CLOUD MODEL FOR THE SWIR AND LWIR PASS BANDS

Mike Scarborough
Bob Pilgrim
Teledyne Brown Engineering

TITLE: AN EMPIRICAL CLOUD MODEL FOR THE SWIR & LWIR PASSBANDS

Authors: TBE, Mike Scarborough, Bob Pilgrim
Sponsor: NV&EOL, Ground Systems, Ted Doepel

ABSTRACT

An empirical approach has been used to synthesize imagery of clouds as recorded in two infrared spectral bands. Statistical parameters characterizing cloud textures in two IR bands were derived from measurements acquired by the U.S. Army's Ground Based Measurement sensor. A simple two-dimensional autoregressive model was used to approximate the texture of cloud images, and a quasi-fractal model was used to generate synthetic cloud boundaries. A procedure for generating sequences of synthetic stochastic cloud images exhibiting credible temporal correlation was developed and implemented.

CLOUD SCENE SYNTHESIS

1. IMAGE MODEL

The generation of synthetic imagery to simulate measured infrared cloud imagery requires the use of a suitable mathematical model. Since cloud structure is highly variable and unpredictable, it is natural to choose for this purpose some type of stochastic model. Although clouds are inherently three-dimensional objects and three-dimensional stochastic models might be considered for their representation, it seems more efficient to attempt to represent the two-dimensional cloud images directly rather than to obtain them by projection of three-dimensional cloud structure onto a plane. This approach affords a choice from among a large number of two-dimensional stochastic models which have been developed for purposes of texture analysis and texture synthesis in the fields of digital image processing and computer image generation.

The literature of texture analysis and texture synthesis was surveyed at some length in an effort to identify a stochastic model which combines the attributes of simplicity of implementation and adequate fidelity of modeling. Since these requirements are obviously mutually antagonistic, a compromise is to be expected in selection of the model.

Study of the literature suggested that a simple two-dimensional autoregressive model should satisfy the requirements, particularly since it has been used with success by others to model cloud imagery (Ref. 1). For this model (as for most others), the image is regarded as a two-dimensional rectangular array of discrete elements (pixels), each of which is described by a pair of indices specifying its location within the array and a value corresponding to the image "brightness" or "gray level" at the point represented. Using the notation $U_{i,j}$ to represent the gray level of the pixel in the ith row and jth column of the array, the general first-order autoregressive model may be written as

$$u_{i,j} = a_1 u_{i-1,j} + a_2 u_{i,j-1} + a_3 u_{i-1,j-1} + \epsilon_{i,j} \qquad (1)$$

where a_1, a_2 and a_3 are constants, and $\varepsilon_{i,j}$ is a white noise process such that $E\left[\varepsilon_{i,j}\varepsilon_{i+k,j+\ell}\right] = \beta^2\delta_{k,0}\delta_{\ell,0}$. Here β is a constant, and $\delta_{m,n}$ represents the Kronecker delta function.

The constants a_1, a_2 and a_3 determine the autocorrelation characteristics of the process defined by $u_{i,j}$. In this study, it is assumed that the structure of cloud imagery is approximately isotropic. Although the simple autoregressive model of Equation 1 is inherently anisotropic, it can be made to approximate the isotropic ideal by choosing $a_1 = a_2 = \rho$ with $a_3 = -\rho^2$. In this case, $\beta = 1 - \rho^2$. Thus, a quasi-isotropic form of the model of Equation 1 is

$$u_{i,j} = \rho u_{i-1,j} + \rho u_{i,j-1} - \rho^2 u_{i-1,j-1} + (1-\rho^2)\varepsilon_{i,j} \tag{2}$$

In this model, $u_{i,j}$ and $\varepsilon_{i,j}$ exhibit the same variance.

It can be shown that the process $u_{i,j}$ generated by the model of Equation 2 has an autocovariance function of the form

$$R(k,\ell) \equiv E\left[(u_{i,j}-\mu)(u_{i+k,j+\ell}-\mu)\right] = \sigma^2\rho^{|k|+|\ell|}, \tag{3}$$

where $E[\cdot]$ denotes the expected value of the enclosed random variable, and $\mu = E[U_{i,j}]$, independent of i and j. The corresponding spectral density function is

$$S(\xi,\eta) = \frac{(1-\rho^2)^2}{[1-\rho\xi-\rho\eta+\rho^2\xi\eta]\,[1-\frac{\rho}{\xi}-\frac{\rho}{\eta}+\frac{\rho^2}{\xi\eta}]} \,. \tag{4}$$

2. IMAGE ANALYSIS

To employ the model of Equation 2 to synthesize imagery representative of a given cloud type, it is necessary to supply numerical values for the model parameters ρ and σ defined in the previous section. These values were determined by empirical means using the available data recorded by the GBM IR telescope. This instrument is located at the Army Optical Station on Roi Namur Island in the Quajalein Atoll where it was used to observe infrared phenomena associated with the re-entry into the atmosphere of ballistic missile warheads.

Incidental to this mission it collected a large amount of two-color infrared data on clouds which happened to be present in the area at the times of re-entry. Using this measured data it is necessary only to compute values of the autocovariance function R(k,0) as defined in Equation 3 for a range of values of the lag parameter k and then to select values for ρ and σ which give the best fit of Equation 3 to the computed autocovariance function. The value of σ^2 may be read off directly as r(0,0), and ρ may then be identified with $R(1,0)/\sigma^2$. Alternatively, the value of may be taken to be exp (-1/k'), where k' is the value of the lag such that $R(k',0)/\ ^2 = \exp(-1)$.

The autocovariance function R(k,0) was computed on selected GBM images, suitably filtered to resemble data as it would appear if recorded by the IRST sensor. For this, purpose a standard statistical subroutine (FTAUTO) from the IMSL Library of mathematical applications routines was employed. The autocovariance of the signal from each of several selected detectors was computed for each detector separately, and then an average over detectors was performed to yield a composite value for R(k,0), k = 1,2,...,80. The resulting composite values were plotted against the lag, k. The plot was then used to read off values of ρ and σ as outlined above.

3. IMAGE SYNTHESIS

Inspection of the autoregressive model of Equation 2 reveals that samples of the process $u_{i,j}$ may be generated recursively provided that values of $u_{1,j}$, j = 1,2,...J and $u_{i,1}$, i = 1,2,...,I are available. That is, given values of $u_{i,j}$ for all pixels in the first row and the first column of the image array, the values of all remaining pixels may be directly determined by successive application of Equation 2. The remaining problem is then to provide values for pixels in the first row and first column of the array.

The approach taken in this study is to supply the required pixel values from a combination of measured data and synthesized values as follows. A typical sample of data from a single GBM detector (suitably filtered to simulate IRST data) consisting of a sequence of 93 successive pixels is used as the input "time series" to SUBROUTINE FTCMP of the IMSL Library. This routine performs an analysis of a time series based on a stochastic autoregressive integrated moving average (ARIMA) model. It develops values of required model parameters from the given time series and then uses these values to synthesize a continuation of the stochastic process for future time. With the 93-pixel sample as input, FTCMP was used to extrapolate the sequence to give a total of 512 samples. These 512 samples were then used as the values of $u_{1,j}, j = 1,2,\ldots,512$ and again as values of $u_{i,1}$, $i = 1,2,\ldots,512$. A straightforward application of Equation 2 using values of ρ and σ obtained as described in the preceding section then permitted filling of the remainder of the array.

The procedure described above may be used to synthesize homogeneous cloud images, but of greater interest in the present application are celestial scenes containing a mixture of cloud and clear sky. The approach used in this study to generate such images is sometimes referred to as the Background-Foreground model. In this model, the image array is suitably partitioned into regions of two types. Although the terms "background" and "foreground" are conventionally used to label these regions, "sky" and "cloud" will serve better here. Homogeneous images of sky and cloud are generated as described above, and the partitioned array is used as a guide in constructing a composite image using the following simple algorithm. Pixels in the partitioned image are examined sequentially, and their type ("sky" or "cloud") is noted. If the pixel type is "sky," the value of the pixel at the corresponding location in the homogeneous sky image is inserted into the composite image at the corresponding location. Similarly, if the type "cloud" is noted, the pixel at the corresponding location in the composite image is assigned the value of the pixel at the corresponding position in the homogeneous cloud image.

Use of the Background-Foreground approach introduces two new problems: How is the partitioning to be accomplished to give a realistic (irregular) boundary line separating "cloud" and "sky" regions? How can the abrupt transition which will occur at the boundary be made more realistic without additional processing?

The partitioning problem is solved by employing a stochastic interpolation scheme proposed by Fournier, Fussell, and Carpenter (Ref. 2) to approximate fractal curves. It has been shown (Ref. 3) that cloud perimeters are fractal curves of fractal dimension $D = 1.35$. The method of Reference 2 permits the generation of a fractal curve of the appropriate fractal dimension between any pair of points in a plane. In the present application, one of these points is chosen to lie on the upper boundary of the image plane, while the second point is chosen to lie on the lower boundary. The fractal curve connecting these two points thus divides the image roughly into left and right regions which may be identified with "sky" and "cloud", respectively. A slight modification of the method of Reference 2 permits the introduction of a controlled degree of convexity into the generated curve to simulate the "fluffy" appearance of clouds. Without this feature, any curves generated would be statistically symmetrical, and the assignment of "sky" and "cloud" values to left and right regions would be completely arbitrary. The convexity parameter introduced is simply a constant bias value added to the random variable used in the stochastic interpolation algorithm of Reference 2. Since no empirical value for this bias has been reported, a value (0.02) was selected which appears visually to yield credible cloud contours.

Plots of infrared cloud data for scans which intersect cloud boundaries typically exhibit a gradual decrease in cloud radiance as the cloud-sky boundary is approached from the "cloud" side. In addition, as the cloud becomes more tenuous near the boundary, there may be "holes" in the cloud through which the sky may be seen. To represent these effects, the "cloud" portion of the image is modified as follows.

Let $C(x,y)$ and $S(x,y)$ represent the cloud and sky radiances at point (x,y) in the two homogeneous regions, respectively. Consider a single horizontal scan line (row of pixels) from the image corresponding to a constant value of y, and suppose that the cloud boundary intersects this scan line at the point (x_1,y) with "cloud" corresponding to $x \geq x_1$, "sky" to $x < x_1$. We define a modified cloud radiance $C'(x,y)$ for $x \geq x_1$ by $C'(x,y)$ = greater of $(S(x,y)$ and $C(x,y) - C(x_1,y) \exp ,-(x-x_1)/d)..$ Here, d is a characteristic length, determined empirically, which provides a measure of the rate of decrease of cloud radiance as the cloud-sky boundary is approached. In the case where the horizontal scan line,

y, intersects the boundary at two points, x_1 and x_2, with the interval (x_2,x_2) corresponding to "cloud", the expression for $C'(x,y)$ with $x_1 < x < x_2$ is

$$C'(x,y) = \text{greater of } (S(x,y) \text{ and } C(x,y)-C(x_1,y)\exp(-(x-x_1)/d)-C(x_2,y)\exp(-(x_2-x)/d)).$$

Figures 1 and 2 are graphic representations of cloud scenes generated using the method described above. They represent clouds generated based on the data for LWIR and SWIR passbands, respectively.

4. TEMPORAL PROPAGATION

In addition to the ability to synthesize textures resembling the spatial distribution of infrared radiation observed in clouds, it is also desirable to be able to simulate the evolution of these distributions in time. Given a synthetic radiance distribution at time $t = t_a$ represented by an array of pixels $a_{i,j}$, such a model would be capable of providing a credible distribution $b_{i,j}$ over the same set of pixels at a later time $t = t_b$. Any model proposed for generating the array $b_{i,j}$ should exhibit certain statistical characteristics. Thus, in general, the array $b_{i,j}$, while differing in a random manner from $a_{i,j}$, should nevertheless be correlated with $a_{i,j}$ to a degree dependent on the value of the time difference $t_b - t_a$. In particular, when $t = t_a$, the model must predict $b_{i,j} = a_{i,j}$ for all i and j. For t_b greater than t_a, the model should predict a monotonically decreasing value of the quantity $E\left[a_{i,j}b_{i,j}\right]$ as the difference $t_b - t_a$ increases, and in the limit as t_b approaches infinity, the expected value $E\left[a_{i,j}b_{i,j}\right]$ should approach zero. In addition, the spatial covariance properties of the b-array should be identical to the corresponding properties of the a-array for all values of t_b and t_a, at least for time differences $t_b - t_a$ on the order of a second. In particular, we must have $E\left[b_{i,j}\right] = E\left[a_{i,j}\right]$ and $E\left[b_{i,j}b_{i+h,j+k}\right] = E\left[a_{i+h,j+k}\right]$ for all integral values of i, j, h, and k.

Consider a model for $b_{i,j}$ of the form

$$b_{i,j} = pa_{i,j} + \sqrt{1 - p^2} \quad c_{i,j}$$

where E $a_{i,j}$ = 0, and $c_{i,j}$ is a new array generated using the same stochastic process as that used in generating the a-array but statistically completely independent of the a-array. That is,

$$E \left[a_{i,j}a_{i+h,jk}\right] = E \left[c_{i+h,j+k}\right]$$

for any i, j, h, and k, but

$$E \left\{a_{i,j}c_{i+h,j+k}\right\} = 0$$

for all i, j, h, and k. Then we have

$$E \left[b_{i,j}b_{i+h,j+k}\right] = p^2 E \left[a_{i,j}a_{i+h,j+k}\right]$$
$$+ (1 \; p^2) \; E \left[c_{i,j}c_{i+h,j+k}\right] = E \left[a_{i,j}a_{i+h,j+k}\right].$$

The parameter p is a function of the time t at which the distribution is given by $b_{i,j}$. The array $c_{i,j}$ may be thought of as the radiance distribution existing after an infinite time has elapsed following observation of the distribution $a_{i,j}$ at time t_a. A reasonable model for the dependence of p on the time difference $t_b - t_a$ is

$$p \, (t_b - t_a) = \exp \left[-(t_b - t_a)/\tau\right].$$

where τ is the characteristic time associated with the evolution of the radiance distribution. The value of τ could be determined empirically. With this expression for p, the bodel for $b_{i,j}$ becomes

$$b_{i,j} = \exp \left(-(t_b - t_a)/\tau\right) a_{i,j}$$
$$+ \sqrt{1 - \exp \, (-2(t_b - t_a)/\tau} \quad c_{i,j}$$

which satisfies the requirements discussed above.

An interpolated image was generated as shown in Figure 3, such that the correlation coefficient p=.8 was assumed for the intermediate image. For this proceedure to provide a legitimate time sequence of images, the relationship between the correlation coeffient and elapsed time must be determined. Current analysis suggests that this relationship is derivable from statistical image measurables.

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1. "Synethetic Cloud Scenes for IRST Clutter Modeling", IRIS Proceedings, Specialty Group on Targets, Background, and Discrimination of Feb 1984, J. H. Allen, J. D. Malick, A. T. Maksynmowicz, E. S. Claflin, M. R. Hess

2. Computer Rendering of Stochastic Models, Communications of the ACM, A. Fournier, D. Fussel, and L. Carpenter, Volume 25, Number 6, p. 371 June 1982

3. Area-Perimeter Relation for Rain and Cloud Areas, by S. Lovejoy in Science, Vol. 216 9 April 1982, p. 185

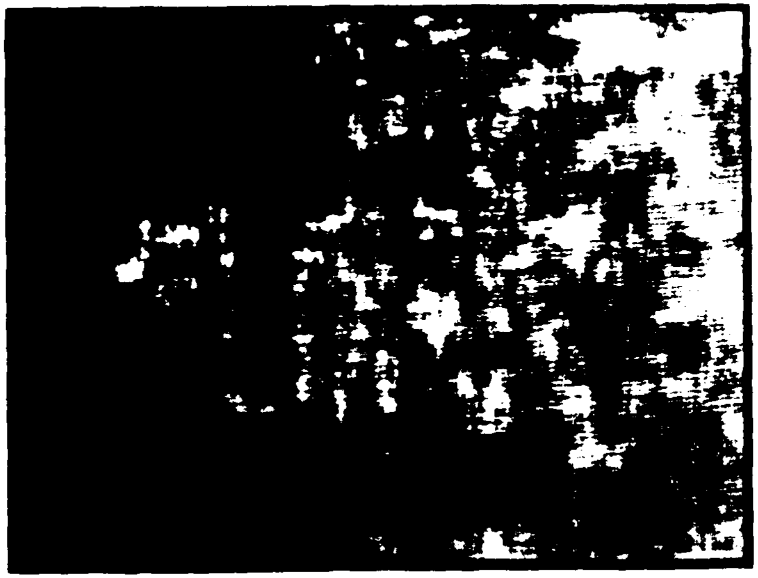


Figure 1a. LWIR, Case 60, Simulated Cloud Image

Figure 1b. SWIR, Case 60, Simulated Cloud Image

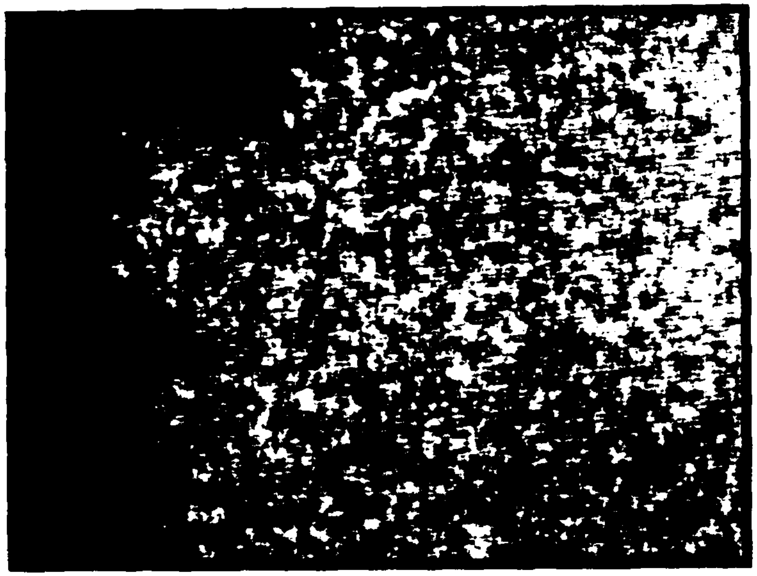


Figure 2a. LWIR, Case 32, Simulated Cloud Image

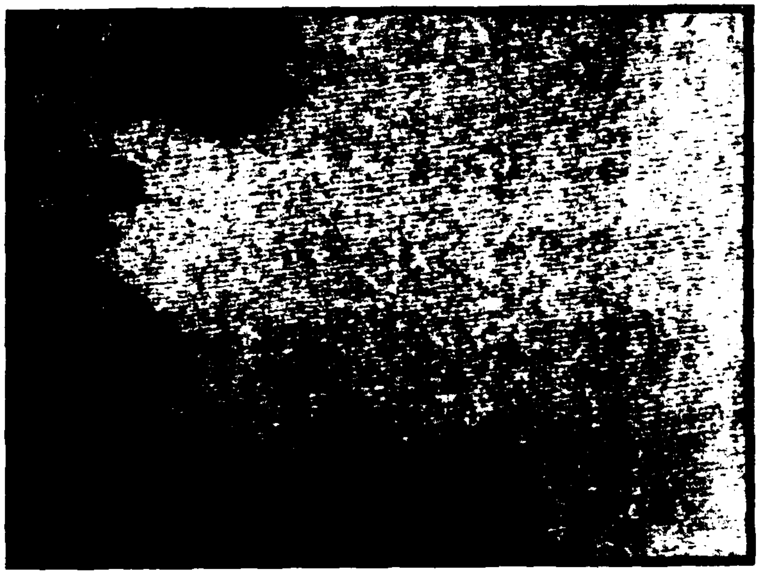
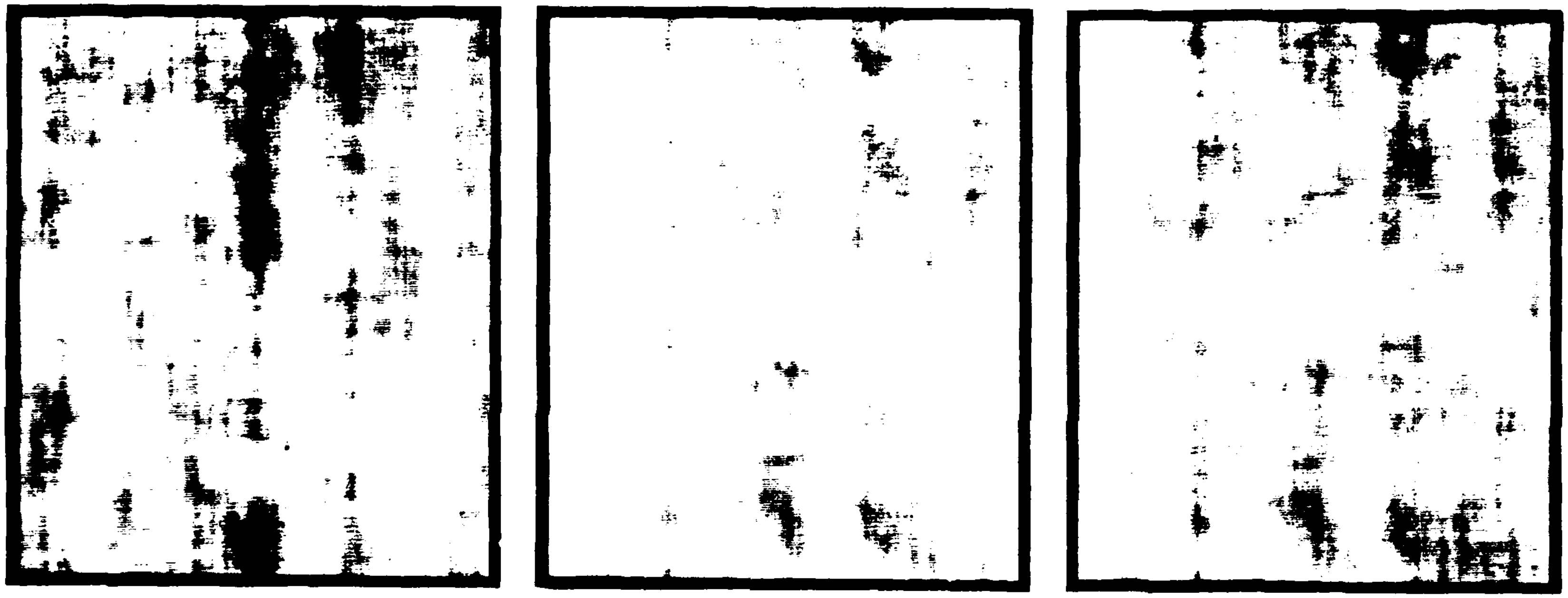


Figure 2b. SWIR, Case 32, Simulated Cloud Image



a) Texture image at $t = 0$. b) Interpolated image $p = .8$ c) Texture image at $t = \infty$.

Figure 3. Temporal propagation of synthetic cloud imagery requires a knowledge of the expected correlation coefficient, p.

ASSESSMENT OF THE LOWTRAN 6 CIRRUS MODEL

John Hornstein
Naval Research Laboratory

ASSESSMENT OF THE LOWTRAN6

CIRRUS MODEL

JOHN HORNSTEIN
NAVAL RESEARCH LABORATORY
WASHINGTON, DC

Assessment of the LOWTRAN6 Cirrus Model

John Hornstein
Optical Sciences Division
Naval Research Laboratory
Washington, DC 20375

LOWTRAN6 provides a model of transmittance through cirrus clouds (but not emission or reflection from these clouds), for wavelengths spanning the near ultraviolet through the thermal infrared. The model rests on three assertions, whose most general forms are: (1) extinction in cirrus clouds depends only on condensed water content; (2) extinction varies negligibly over the cited wavelength range; (3) condensed water content depends only on cloud thickness. The present paper asseses the validity of these assertions, both in their general forms and as they are implemented in LOWTRAN. The first assertion is supported by both theory and experiment, but only over a restricted spectral range whose location and width depend on the sizes of the condensed particles. Because cirrus particles are large, this valid spectral range starts at wavelengths somewhat larger than the upper wavelength limit claimed for the model. The second assertion is not true over the large spectral range of the model: several combined lidar and infrared experiments on cirrus found cirrus to be four to six times more transparent in the visible than in the far infrared. The third assertion is contradicted by most published measurements on optical variations within single cirrus clouds. Physical arguments suggest that it is correct in a rough and qualitative way for comparisons between average or peak values between different cirrus systems, but there is no reason to hope for widely applicable numerical values of the parameters. Because the asserted relation is not applicable within a single cirrus cloud or system, the current LOWTRAN6 model is not appropriate for modeling texture within a cirrus cloud. The LOWTRAN cirrus transmittance model can be corrected without great difficulty, but this will require revision of its built-in numerical parameters. In addition to the reasons already given, revision is needed because the current values are based on flux transmittances, whereas LOWTRAN needs radiance transmittances. A simple way of making this correction will be described. Some effects of the nonspherical shape of cirrus particles can also be estimated simply.

The LOWTRAN6 Cirrus Model

F.F. HALL, JR.

M.J. POST

R.A. RICHTER NOAA

G.M. LERFALD

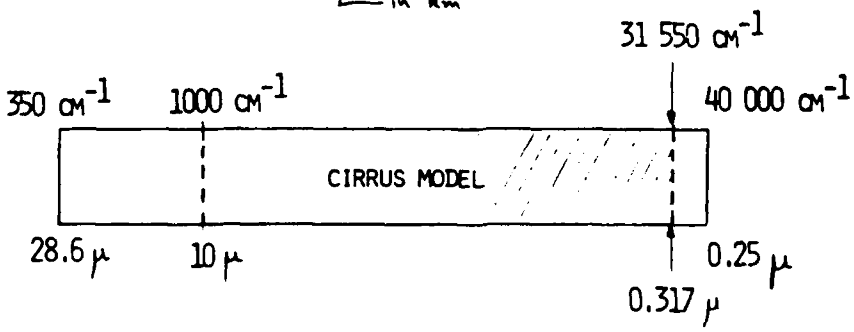
V.E. DERR

$$T = e^{-0.14\,(\Delta z)^2/\mu}$$ TRANSMITTANCE

$$\tau = 0.14\,(\Delta z)^2/\mu$$ OPTICAL DEPTH

$$\sigma_{ext} = 0.14\,(\Delta z)/\mu$$ EXTINCTION COEFFICIENT PER UNIT VOLUME: KM^{-1}

in km



ASSUMPTIONS

GENERAL FORM

- EXTINCTION DEPENDS ONLY ON CONDENSED WATER CONTENT, AND IS ONLY WEAKLY DEPENDENT ON WAVELENGTH OVER CITED RANGE.
- CONDENSED WATER CONTENT DEPENDS ONLY ON CLOUD'S THICKNESS.

AS IMPLEMENTED IN LOWTRAN6

- EXTINCTION IS DIRECTLY PROPORTIONAL TO CONDENSED WATER CONTENT.
- CONDENSED WATER CONTENT IS DIRECTLY PROPORTIONAL TO CLOUD'S THICKNESS.

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EXTINCTION VS. CONDENSED WATER CONTENT

$$\sigma_{ext} = \sum_i \pi r_i^2 \; Q_{ext}(r_i) \cdot \Delta N_i$$

$$CWC = \rho \cdot \sum_i \frac{4}{3} \pi r_i^3 \cdot \Delta N_i \qquad \text{3RD MOMENT}$$

HOW σ_{EXT} CAN BE $\simeq$ A THIRD MOMENT:

IMPORTANT $r_i^2 \Delta N$

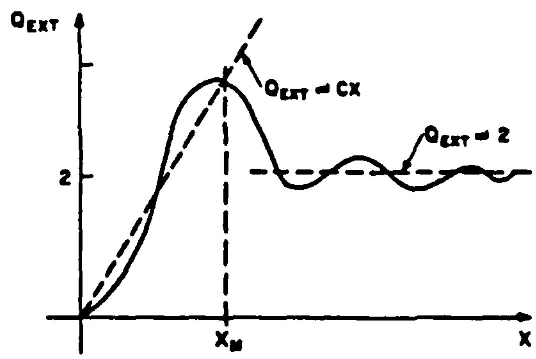

FIG. 1. Schematic behavior of the normalized extinction cross section (efficiency for extinction) Q_{ext} as a function of the size parameter x. In the region $x \gg 1$, Q_{ext} is usually approximated by its asymptotic value $Q_{ext}=2$. If the droplet size distribution spans from $x=0$ to $x=x_M$, $Q_{ext}(x)$ can be approximated [for the purpose of evaluation of an integral in Eq. (4)] by a straight line $Q_{ext}(x)=cx$.

CHÝLEK, JL. ATMOS. SCI. 35, 296 (1978)

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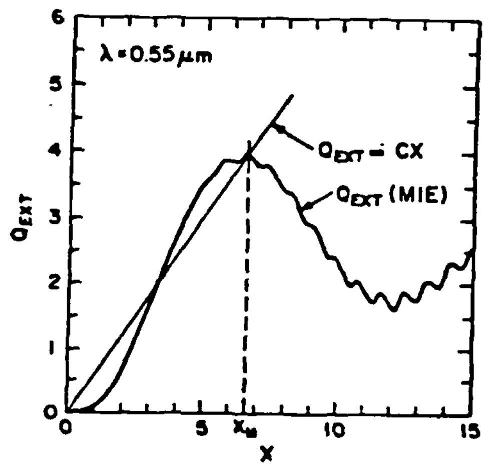


FIG. 2. Normalized extinction cross section Q_{ext} for water droplets at wavelength $\lambda=0.55$ μm (index of refraction $m=1.333$) and its approximation by a straight line $Q_{ext}(x)=cx$ for $x\leq x_M$. The approximation overestimates the exact value of Q_{ext} at small size parameters x, and underestimates it at larger x (still with $x\leq x_M$). These two errors tend to cancel out in the evaluation of the integral in Eq. (4).

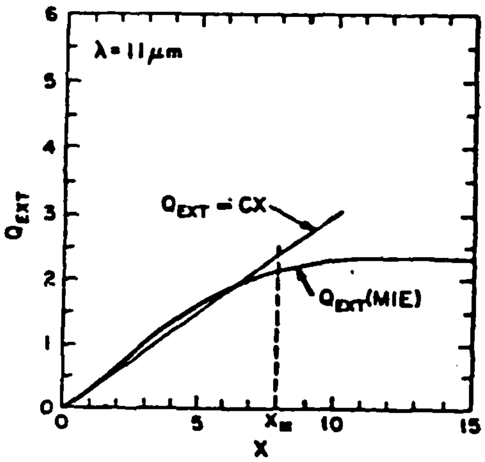
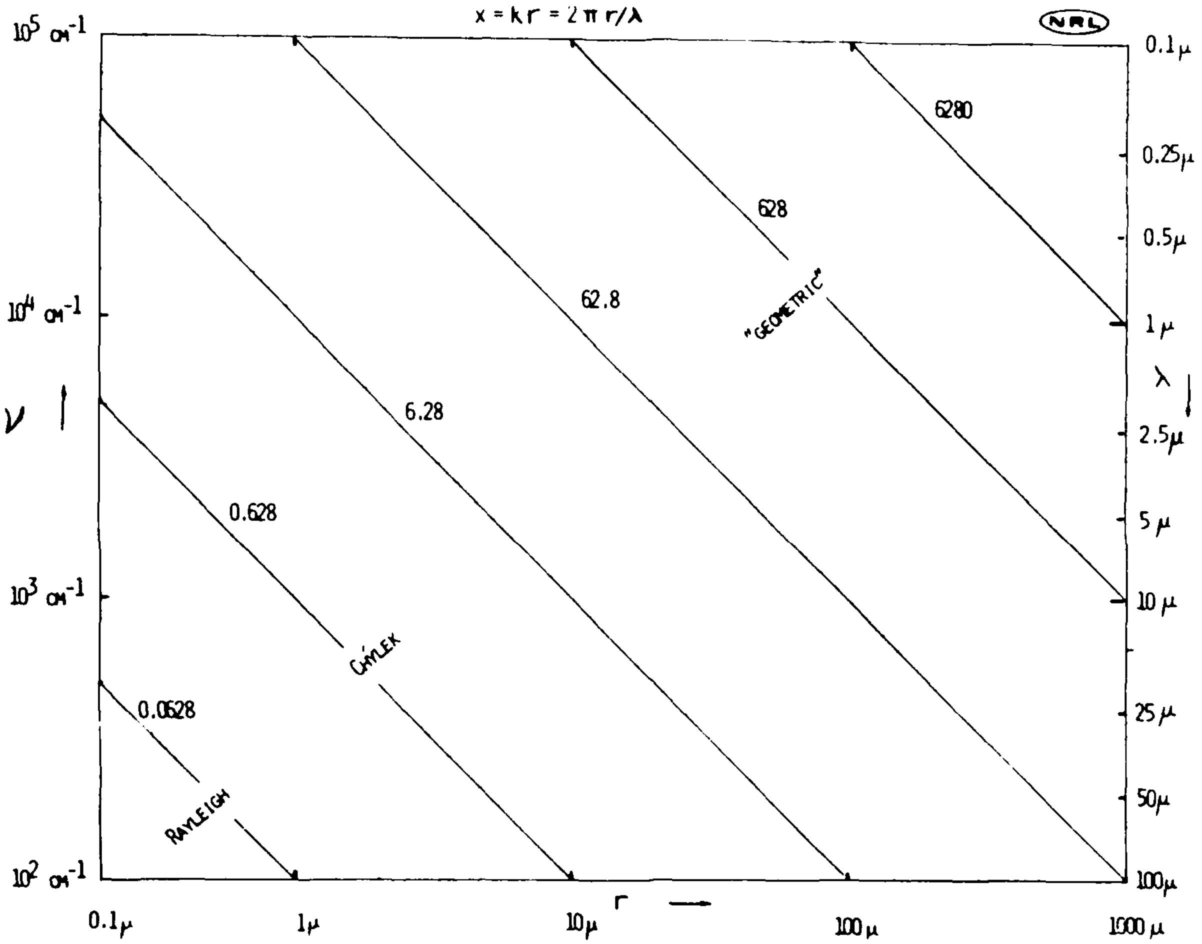


FIG. 3. As in Fig. 2 except at $\lambda=11$ μm. Due to the strong absorption ($m=1.153-0.0968i$) at this wavelength the character of the $Q_{ext}(x)$ curve differs from that at $\lambda=0.55$ μm. Still the curve can be approximated by a straight line $Q_{ext}=cx$ for $x\leq x_M$. If the considered size distribution spans up to x_M the effect of underestimating Q_{ext} in one region and overestimating it in another region cancels out in the integral in Eq. (4). If only small droplets are present, cancellation does not take place and the $Q_{ext}=cx$ approximation is less accurate.

CHÝLEK, JL. ATMOS. SCI. 35, 296 (1978)



x = kr = 2π r/λ
NRL
10^5 cm^-1
10^4 cm^-1
10^3 cm^-1
10^2 cm^-1
ν
0.1μ
0.25μ
0.5μ
1 μ
λ
2.5μ
5 μ
10 μ
25 μ
50μ
100μ
0.1μ
1μ
10μ
r
100 μ
1000 μ
6280
628
62.8
"GEOMETRIC"
6.28
0.628
GAYLEX
0.0628
RAYLEIGH

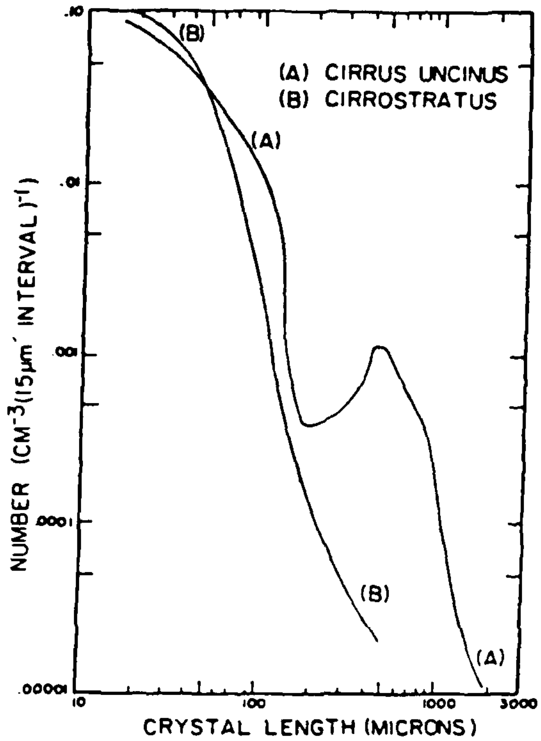
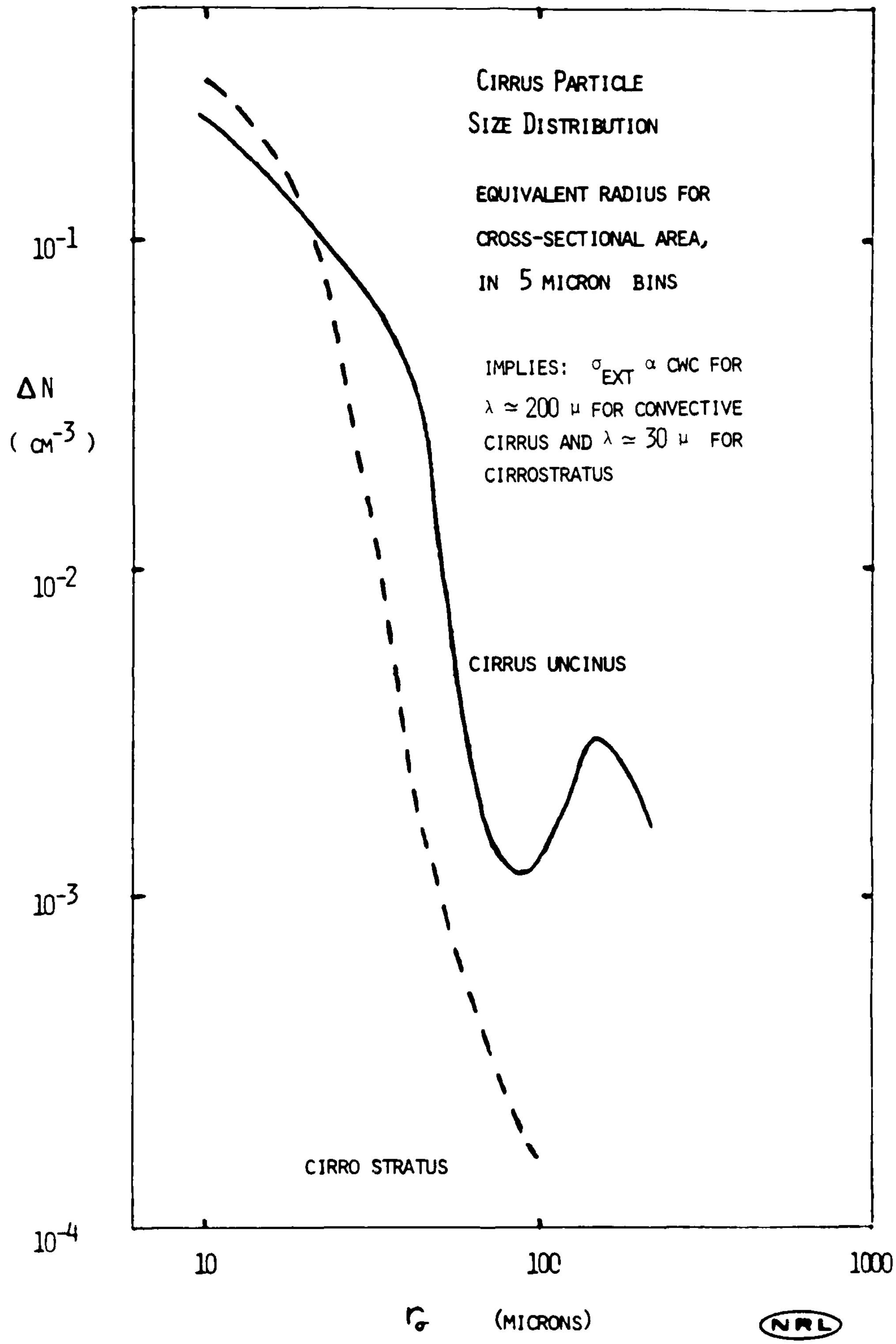


FIG. 3. Particle spectra taken in the downshear region near the base of the head of a cirrus uncinus cloud (A) and near the top of a cirrostratus deck (B).

A. HEYMSFIELD, JL. ATMOS. SCI. 32 , 799 (1975)

NRL



CIRRUS PARTICLE
SIZE DISTRIBUTION
EQUIVALENT RADIUS FOR
CROSS-SECTIONAL AREA,
IN 5 MICRON BINS
IMPLIES: $\sigma_{EXT} \propto$ CWC FOR
$\lambda \simeq 200\ \mu$ FOR CONVECTIVE
CIRRUS AND $\lambda \simeq 30\ \mu$ FOR
CIRROSTRATUS
CIRRUS UNCINUS
CIRRO STRATUS
ΔN
(CM^{-3})
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10
100
1000
r_{σ} (MICRONS)
NRL

SHOWS THAT $\sigma_{EXT} \propto$ CWC WHERE EXPECTED, AND NOT WHERE NOT EXPECTED. FOR SMALLER SIZED PARTICLES IN WATER CLOUDS, EXPECT VALIDITY FOR $10\ \mu < \lambda < 100\ \mu$.

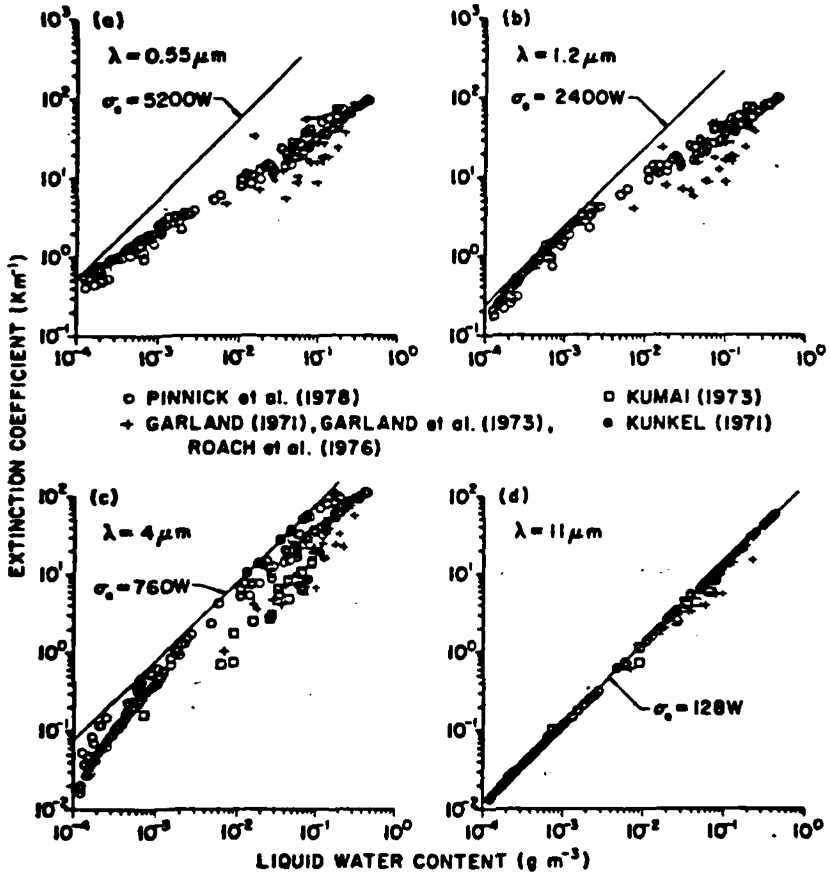


FIG. 1. Variation of extinction coefficient with liquid water content in atmospheric fog and haze for 341 size distribution measurements made at different geographic locales and under a variety of meteorological conditions. In the infrared spectral region around $\lambda = 11\ \mu m$ (d) there exists a linear, size-distribution-independent relation between the volume extinction coefficient σ_e(km^{-1}) and the liquid water content W (g m^{-3}) of the form of Eq. (1). Consequently, the results of all measurements are close to a straight line. The predicted relation between extinction σ_e and liquid water content W according to Eq. (1) is shown by the straight line. On the other hand at $\lambda = 0.55\ \mu m$ (a), the $Q_e = cx$ approximation is not satisfied and no unambiguous relation between the extinction and liquid water content exists. The large spread of the points in the graph shows that the extinction coefficient is a function of the size distribution as well as of the liquid water content. As the wavelength is increased to $\lambda = 1.2\ \mu m$ (b) and $\lambda = 4\ \mu m$ (c) the $Q_e = cx$ approximation is satisfied for larger droplets and the relation (1) shown by the straight lines is becoming a more realistic approximation for hazes and fogs.

JL. ATMOS. SCI. 36, 1577 (1979)

NOTE ALSO: σ_{EXT} HAS SMALL SCATTER ABOUT A FUNCTION OF CWC, EVEN WHERE THEY ARE NOT SIMPLY PROPORTIONAL.

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HALL, JR., ET AL (1983), IN LOWTRAN6 GUIDE:

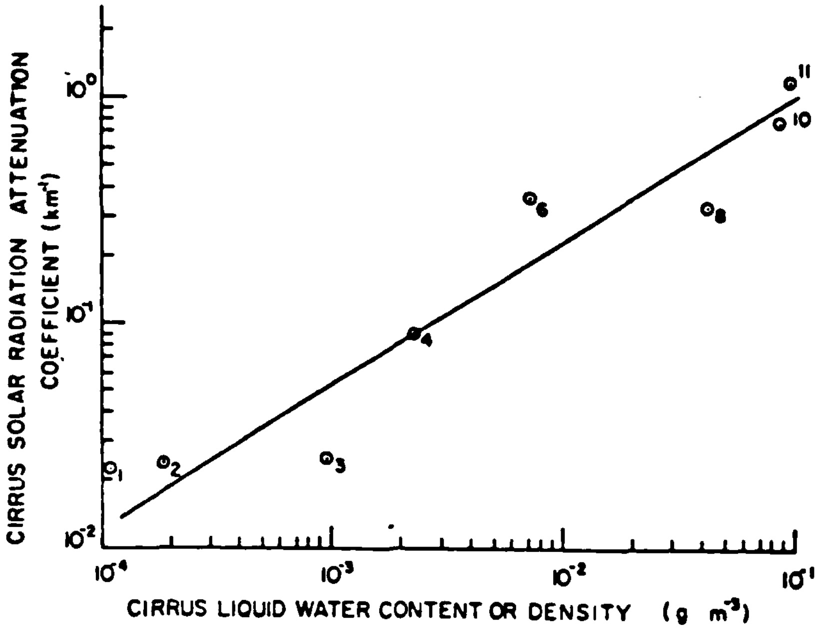

Figure 21. Calculated Cirrus Attenuation Coefficients for Solar Radiation Plotted vs Cloud Liquid Water Content (LWC). Again, the numbers are the cirrus model numbers used by Derr

COMMENTS :

- POWER LAW, BUT SLOPE IS NOT 1 ($\sigma_{ext} = 4.3\ (CWC)^{0.635}$)

- FLUX-BASED, NOT RADIANCE-BASED, AS NEEDED FOR LOWTRAN (CORRECTION GIVES LINE PARALLEL TO AND BELOW THE FIRST)

- INTEGRATED FROM 0.2 TO 10 μ

- DIRECT SPHERES, NOT EQUIVALENT SPHERES

- THEORETICAL, NOT AN EXPERIMENTAL VALIDATION

NRL

WAVELENGTH DEPENDENCE

LOWTRAN6 CIRRUS MODEL ASSUMES WAVELENGTH DEPENDENCE TO BE WEAK.

PLATT AND DAVIS FIND CIRRUS TO BE MUCH MORE TRANSPARENT IN THE VISIBLE THAN IN THE INFRARED. (THIS MUST BE SO, FOR LIDAR TO WORK WELL AS A PROBE OF CIRRUS.)

REASONS FOR EXPECTING A DIFFERENCE:

- SCATTERING IS MORE IMPORTANT THAN ABSORPTION IN THE VISIBLE, WHILE ABSORPTION IS MORE IMPORTANT THAN SCATTERING IN THE IR.
- THE IMPORTANCE OF VARIOUS PARTICLE-SIZE POPULATIONS VARIES WITH WAVELENGTH.

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WHAT SHOULD LOWTRAN DO?

CWC IS CONVENIENT

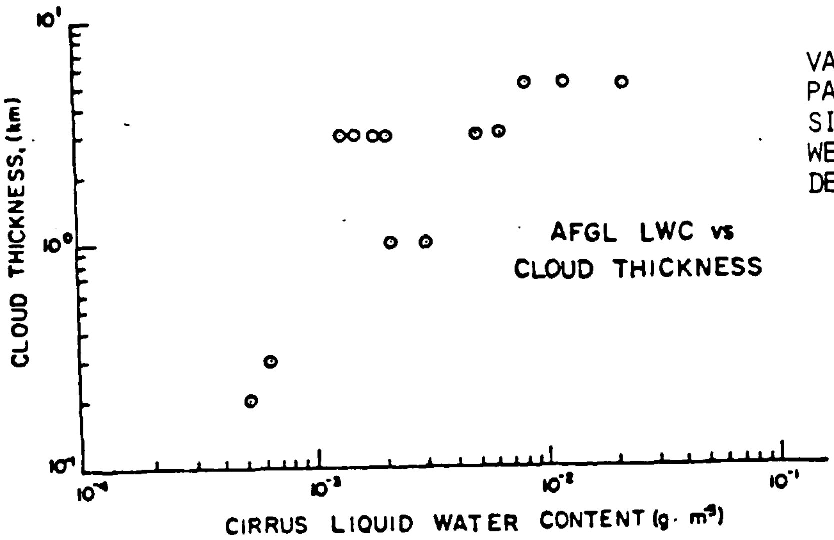
- A SINGLE NUMBER, RATHER THAN A FUNCTION
- DATA IS AVAILABLE

LOG VS. LOG(CWC) IS LOCALLY LINEAR

- $\sigma_{ext} = a(\mathrm{CWC})^b$
- a AND b ARE FUNCTIONS OF: WAVELENGTH
  CWC
  CLOUD TYPE

- EVEN WITH ALL THESE DEPENDENCES (EG., IN A LOOK-UP TABLE), THIS IS STILL AN APPROXIMATION. DIFFERENT PARTICLE SIZE DISTRIBUTIONS WITH THE SAME CWC WILL GIVE SLIGHTLY DIFFERENT EXTINCTION

HALL, JR., ET AL (1983), IN LOWTRAN6 GUIDE:



VARLEY ET AL. MEASURED PARTICLE SHAPES AND SIZES; OBSERVATIONS WERE NOT SUITABLE FOR DERIVING CLOUD THICKNESS.

Figure 22. Cirrus Cloud Thickness vs Liquid Water Content (LWC) From AFGL Measurements

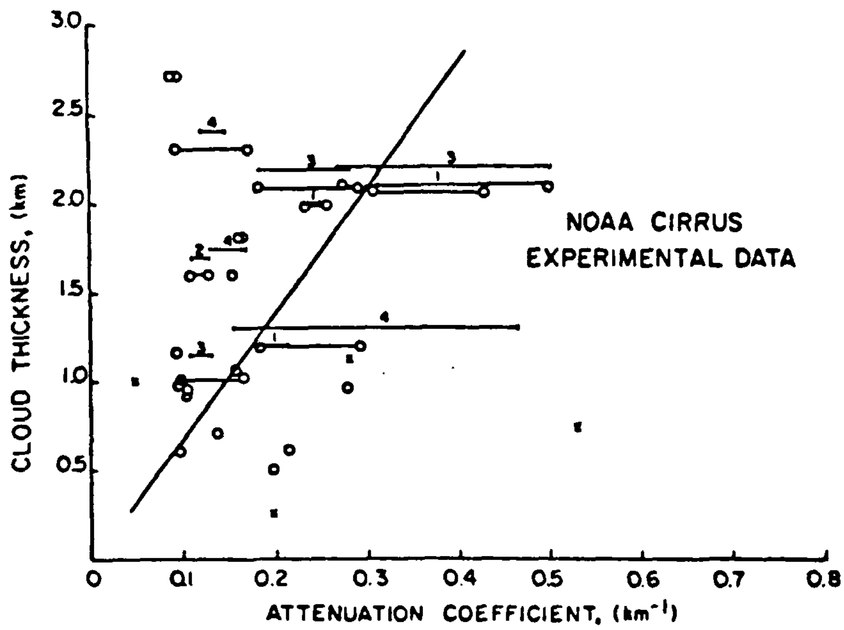


Figure 23. NOAA Measurements of Cirrus Transmittance. Solar irradiance was measured using a nine-channel photometer/radiometer and cloud thickness with a pulsed ruby lidar

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EMISSIVITY

(10 - 12 MICRONS)

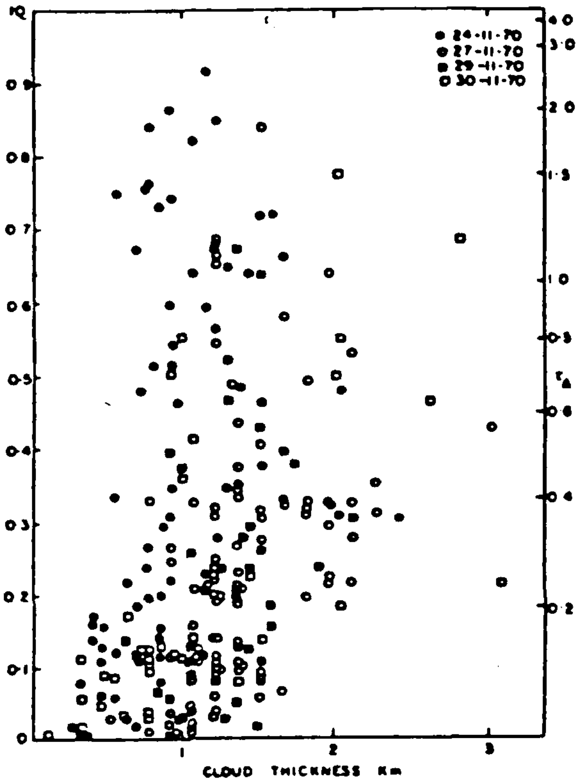

FIG. 2. Emissivity ϵ and optical thickness τ_A of cirrus as a function of cloud vertical thickness h.

FLUX EMISSIVITY, BUT LACK OF CORRELATION APPLIES TO RADIANCE EMISSIVITY, TOO.

NEITHER AVERAGE THICKNESS NOR REPRESENTATIVE MAXIMUM THICKNESS YIELD A CORRELATION.

FROM: C. M. R. PLATT, JL. ATMOS. SCI. 30, 1191 (1973)

NRL

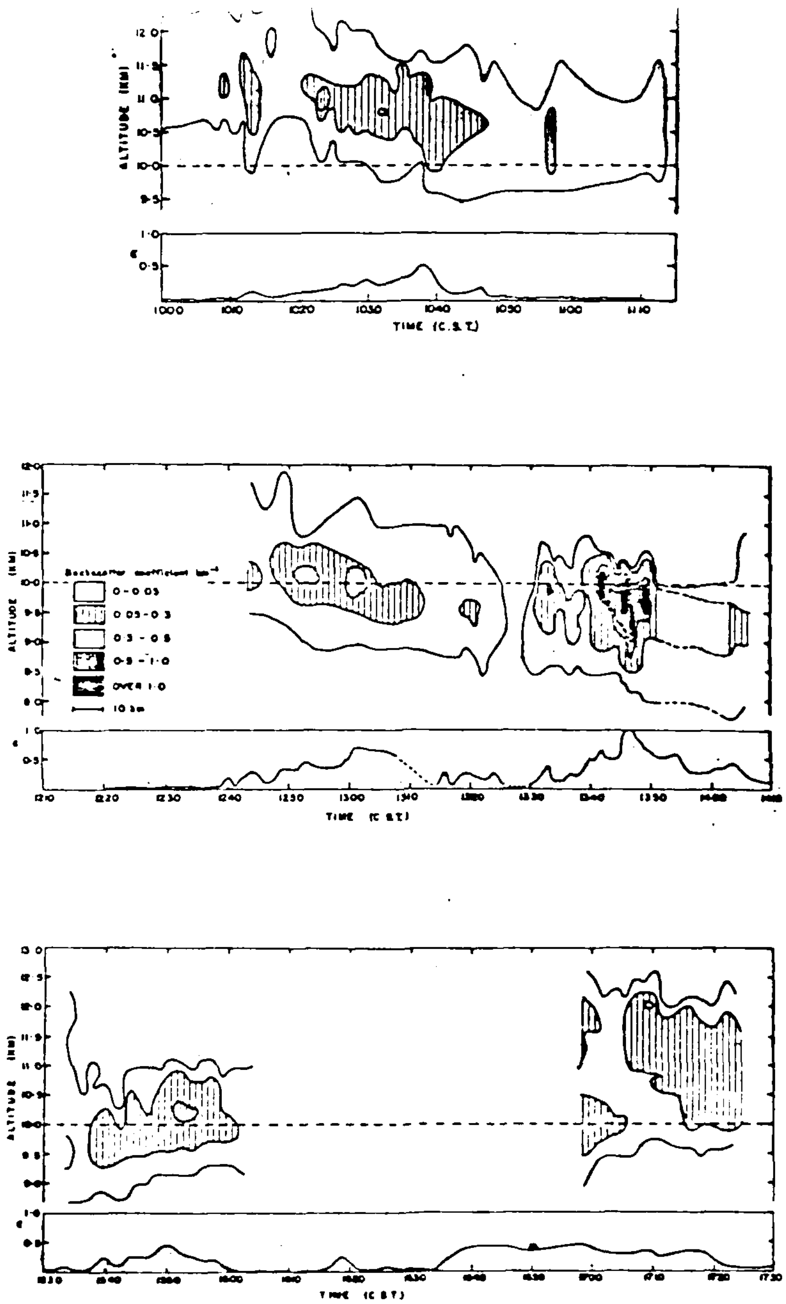

Figure 1. Lidar time-height profiles of the cirrus backscatter coefficient (0·694μm wavelength) in the zenith on 27 November 1970. Simultaneous cloud emissivity ϵ (10–12μm) is plotted below.

PLATT, QUART. JL. ROY. METEOROL. SOC. 101, 119 (1975)

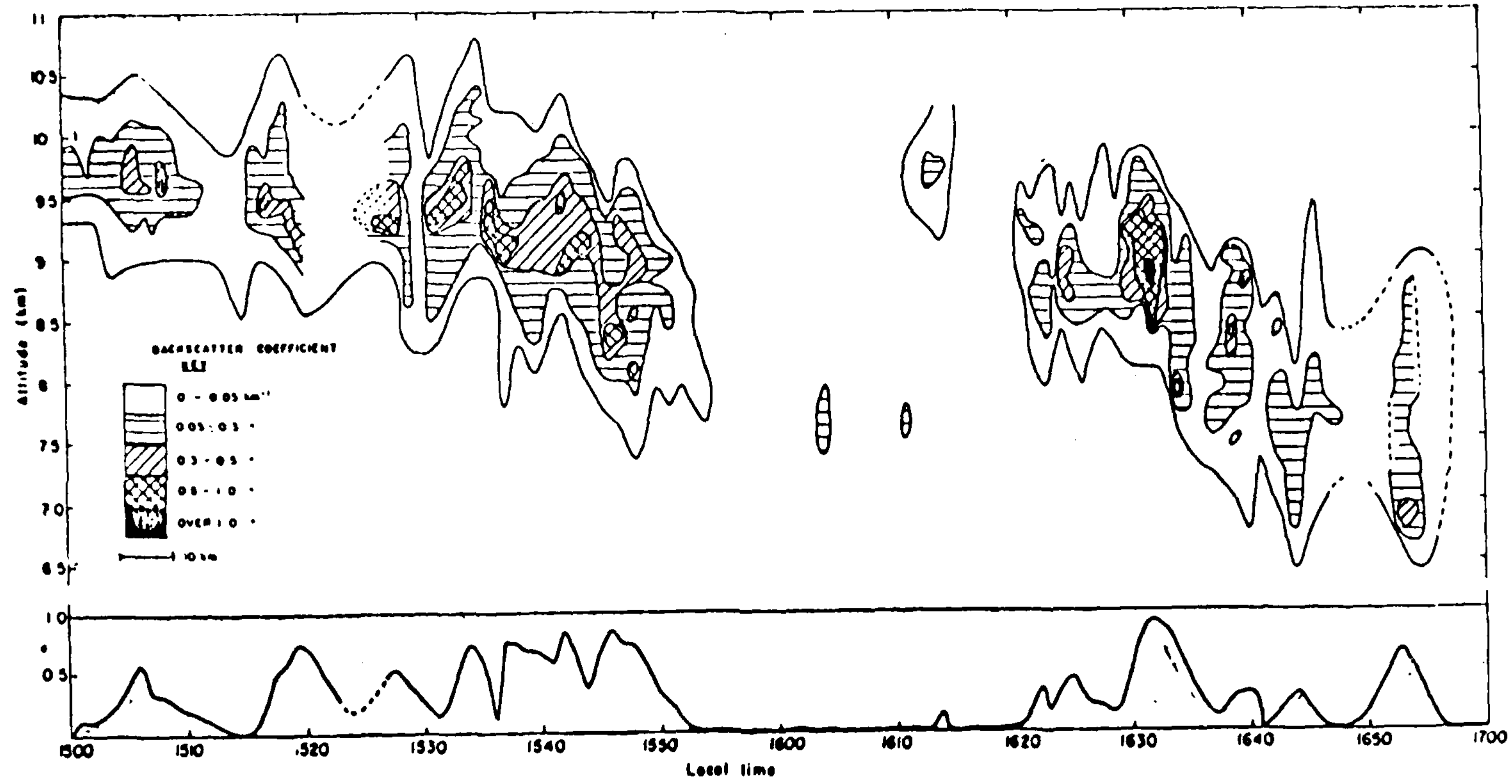

FIG. 7. Time-height profile of observed cirrus backscatter coefficients (taken every minute) for 23 November. The corresponding emissivity at 11 μm is shown below.

PLATT, JL. ATMOS. SCI. 30, 1191 (1973)

NRL

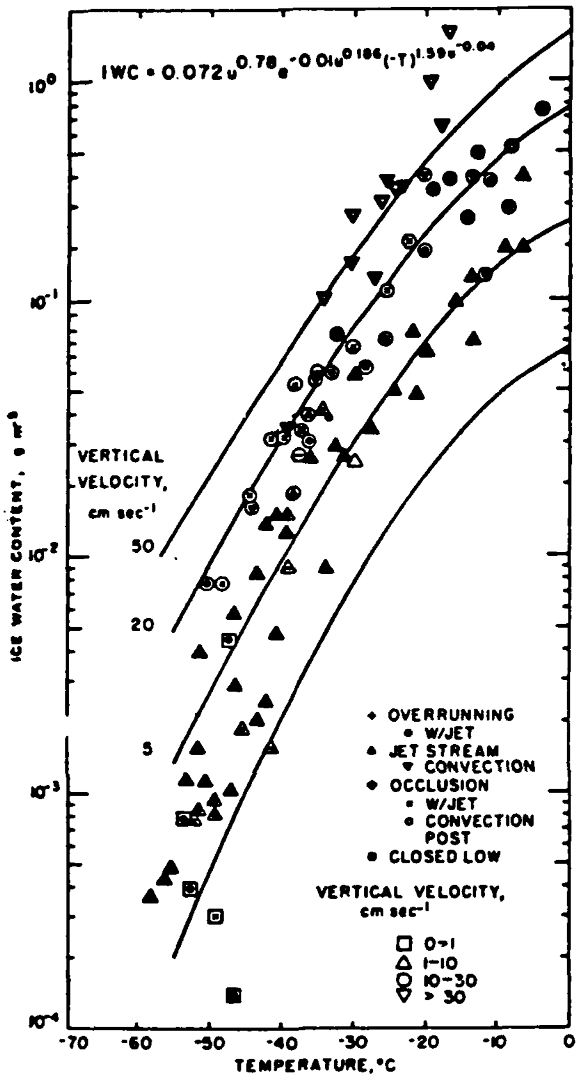

FIG. 5. Ice water content plotted against temperature, and parameterized in terms of the vertical air velocity: inside symbol, synoptic type; outside symbol, vertical velocity range. Best-fit equations to data are indicated.

HEYMSFIELD, JL. ATMOS. SCI. 34, 367 (1977)

NRL

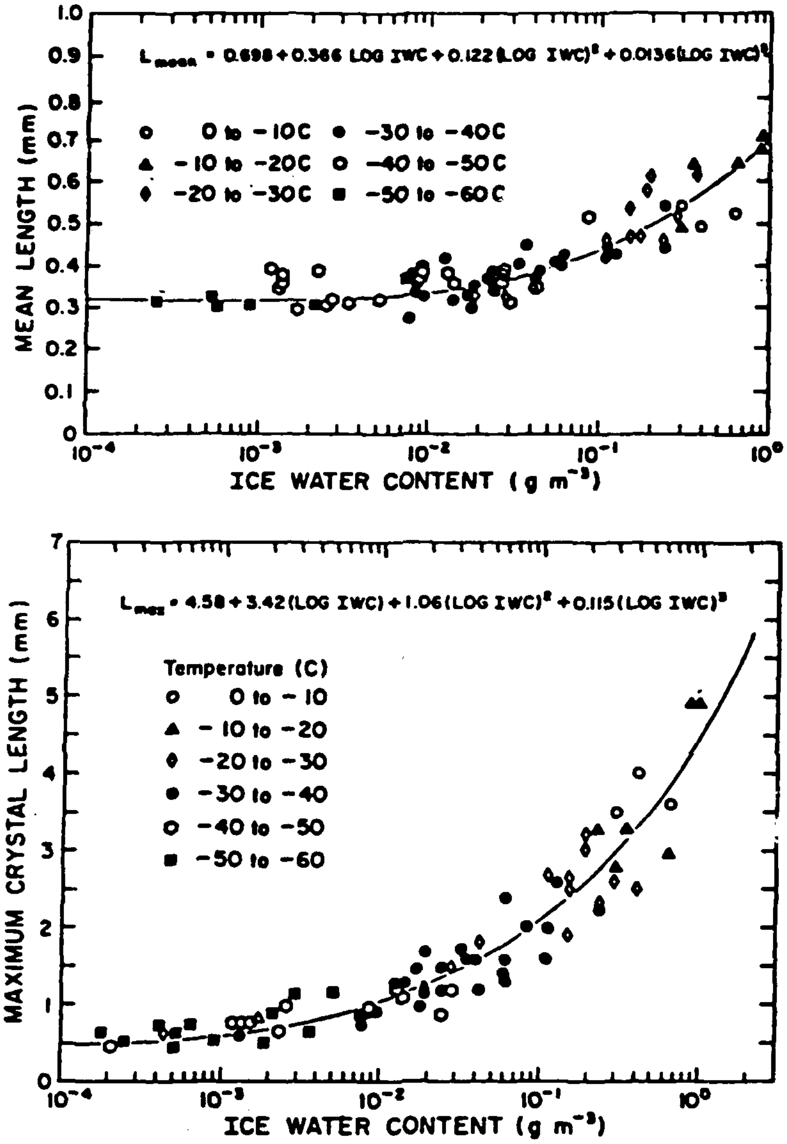

FIG. 7. Mean (a) and maximum (b) crystal lengths plotted against ice water content. Maximum crystal length corresponds to particles in concentrations of 1 m^{-4} per mm size class. Sampling temperature is indicated.

HEYMSFIELD, JL. ATMOS. SCI. 34, 367 (1977)

NRL

HOW LOWTRAN MIGHT DO IT

USER SPECIFIES BASE HEIGHT AND THICKNESS OF CLOUD.

LOWTRAN OBTAINS IN-CLOUD TEMPERATURES FROM ATMOSPHERIC PROFILE.

USER SPECIFIES SEVERITY OF VERTICAL CONVECTION, PROBABLY BY SPECIFYING CIRRUS TYPE.

LOWTRAN INFERRS IWC (AND OTHER MICROPHYSICS) FROM TEMPERATURE, VELOCITY AND POSITION IN CLOUD. THIS DETERMINES OPTICAL PROPERTIES. RANDOM-NUMBER GENERATOR MAY BE USED FOR TEXTURE.

LOWTRAN INTEGRATES ALONG PATH.

INITIALLY, WARN USER THAT VALIDITY IS ASSURED ONLY IN THE FAR IR, UNTIL THE ROLE OF 2 - 20 MICRON PARTICLES CAN BE ASSESSED.

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CIRRUS VS. CONTRAILS

	CIRRUS	CONTRAILS
CWC	≤ 0.5 GM/M^3 (MAX) 0.005 TO 0.05 IS MORE REPRESENTATIVE	≤ 0.1 GM/M^3
COMMON LENGTHS		
POPULATION 1	1 TO 100 μ	
POPULATION 2	400 TO 700 μ	150 TO 450 μ
PARTICLE NUMBERS		
POPULATION 1	10 CM^{-3}	
POPULATION 2	10^{-3} CM^{-3}	$40 \cdot 10^{-3}$ CM^{-3}
PHASE	ICE	ICE, WATER OR MIXED
THICKNESS	½ TO 3 KM	½ TO 1 KM

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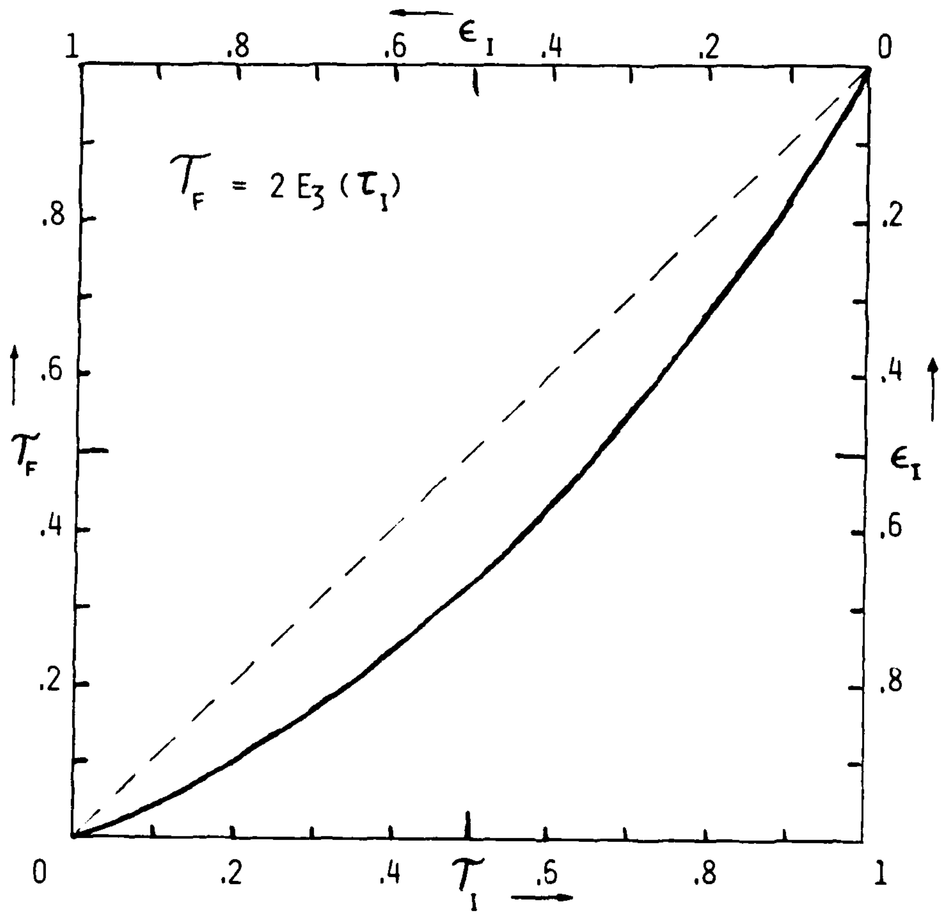
Flux - based vs. Radiance - based Measures of Attenuation and Emission

$\mathcal{T}_F = F_{OUT} / F_{IN}$ $\qquad\qquad$ $\mathcal{T}_I = I_{OUT} / I_{IN}$

$$\mathcal{T} = e^{-\tau} = 1 - \epsilon$$

If monochromatic (or gray), and hemispherically isotropic:



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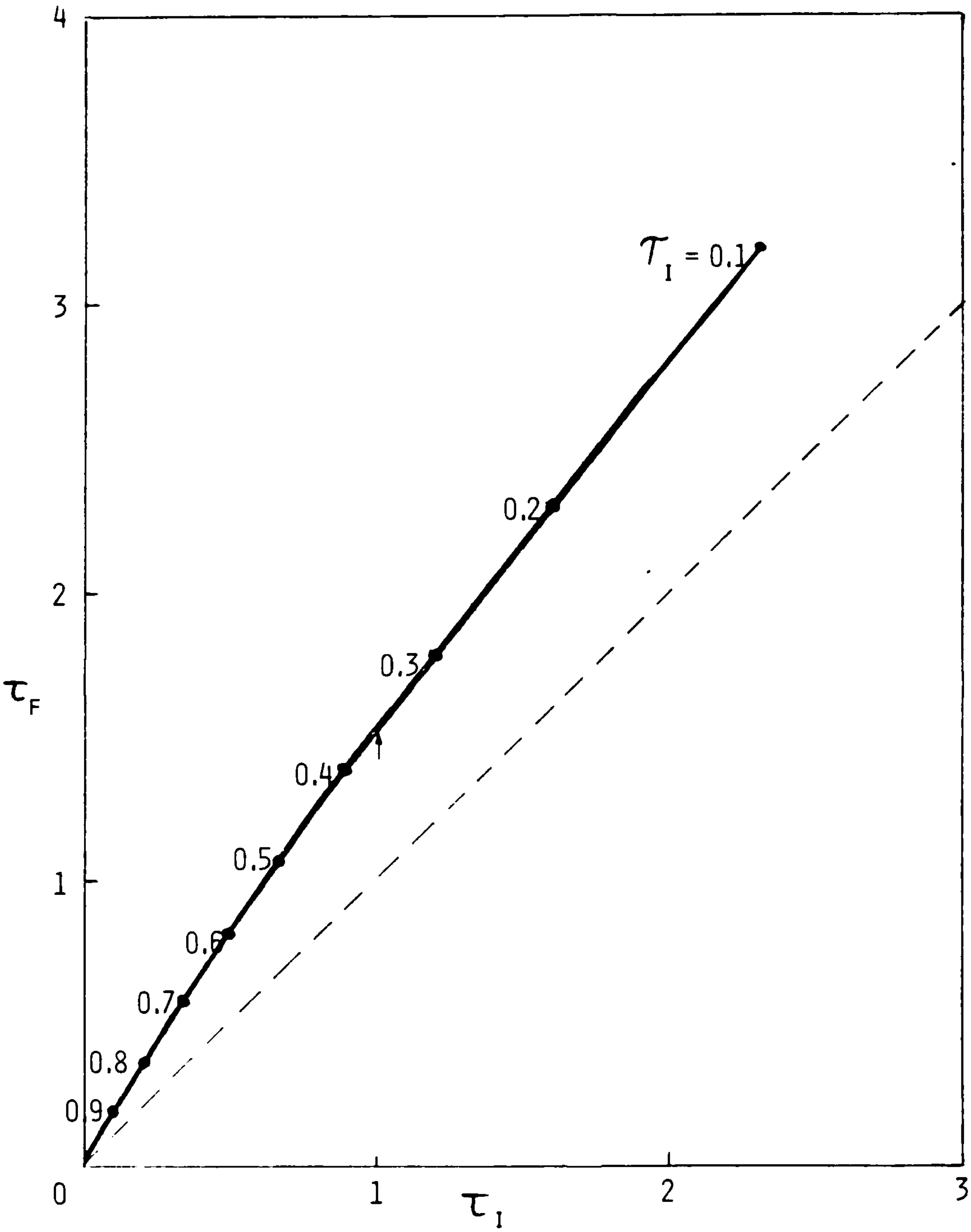

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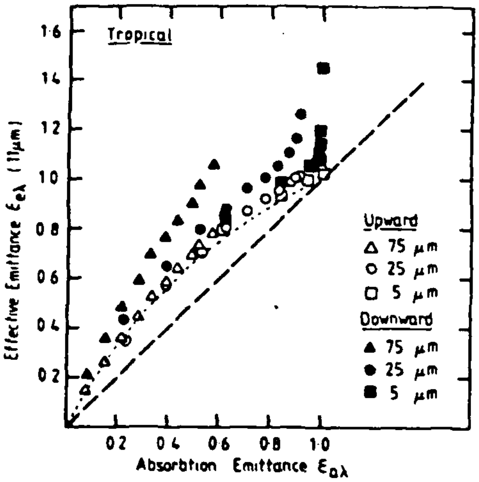


FIG. 9. The 11 μm flux emittance as a function of beam "absorption emittance" for both upward and downward directions and for the three case studies indicated. The calculations were performed for a high cloud positioned in a model tropical atmosphere. The three different sets of points represent the three different ice cylinder radii, as given in Table 1. Dashed line: curve for $\epsilon_{e\lambda} = \epsilon_{a\lambda}$; dotted line: curve for the simple diffuse relation of Eq. (16).

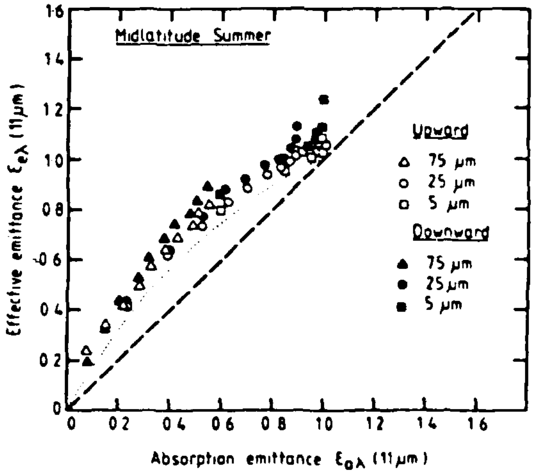


FIG. 10. As in Fig. 9 except for a midlatitude summer atmosphere

DOTTED CURVES FITS $\tau_F = 2E_3(\tau_I)$

PLATT AND STEPHENS, JL. ATMOS. SCI. 37, 2314 (1980)

PROFILES OF OPTICAL EXTINCTION COEFFICIENTS CALCULATED FROM DROPLET SPECTRA OBSERVED IN MARINE STRATUS CLOUD LAYERS

V. Ray Noonkester
Naval Ocean Systems Center

PROFILES OF OPTICAL EXTINCTION COEFFICIENTS CALCULATED

FROM DROPLET SPECTRA OBSERVED IN

MARINE STRATUS CLOUD LAYERS

ABSTRACT

Because marine stratus clouds are persistent in the eastern portion of subtropical high-pressure systems, models of their optical properties are particularly needed for multiple purposes such as atmospheric radiation balance studies and EO system assessments.

Airborne measurements of the water droplet spectra n(r) (r is radius; $0.23\mu m \leq r \leq 150\mu m$) were made at about 14 levels in stratus layers during May and August 1981, 130 km SW of San Diego. Five parameters were calculated from 15 n(r)'s observed along each level extending 6.44 km and from the average n(r) over the entire run. These parameters are the number of droplets N, the mean droplet radius $\bar{r}$, the cross-sectional area A, the liquid water content w and the optical extinction coefficient k for wave lengths λ of 0.53, 3.75 and $10.59\mu m$.

The vertical profile of these parameters revealed features expected for changes in n(r) experiencing adiabatic cooling in vertically rising air. However, the vertical profiles for the May and August data differed in a sense consistent with a differnce in the chemical make-up of the nuclei generally associated with marine and continental air mass, respectively. The division of the data into "marine" (May) and "continental" (August) was supported by other data. The capability of a droplet model (Fitzgerald, JAM, 1975, v. 14,

p. 1044) to duplicate closely w and A below the cloud base on a selected "marine" and "continental" day, using NaCl and $(NH_4)_2\ SO_4$ nuclei, respectively, provided strong support on the air mass classification and on the adiabatic nature (well-mixed layer) of the stratus layers.

The data supported the conclusion that the saturation level, the cloud base, was near the elevation where $w=0.02$ gm m^{-3}.

Vertical profiles of k (3λ's) were constructed as a function of the distance from the defined cloud base z^* in the range $-300m \leq z^* \leq 200m$. An approximation to the k's, a power function of w, was found to be superior compared with approximations involving linear functions of w or A. However, the power function varies with air mass.

The horizontal variability of the k's was greater near cloud base and top, but the k's were highly correlated. The k's were approaching the same value near $z^*=200m$. The scale size of the horizontal variations was near 3 km on two selected days. Both vertical and horizontal optical paths would be influenced by variations at this scale size.

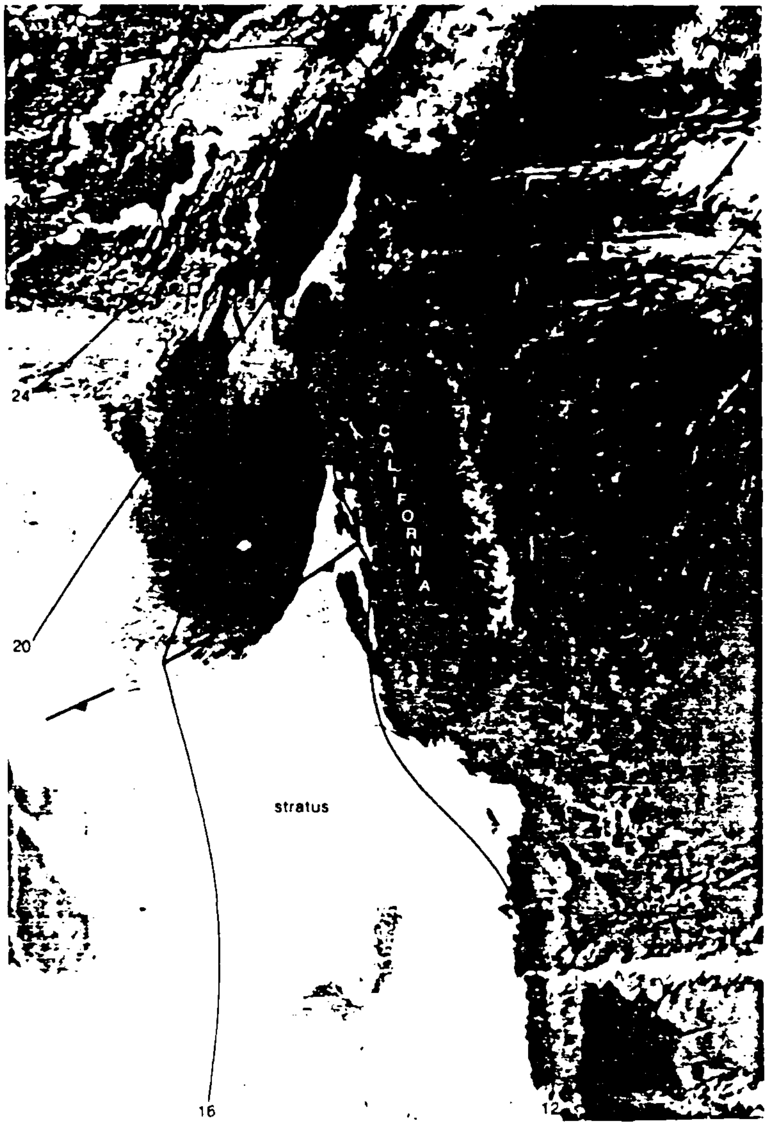
Sampling problems including artificial variability created by small sampling volumes of the spectrometer and the path lengths required for reliable estimates of n(r) are also considered.

PROFILES OF OPTICAL EXTINCTION COEFFICIENTS
CALCULATED FROM DROPLET SPECTRA
OBSERVED IN MARINE STRATUS CLOUD LAYERS

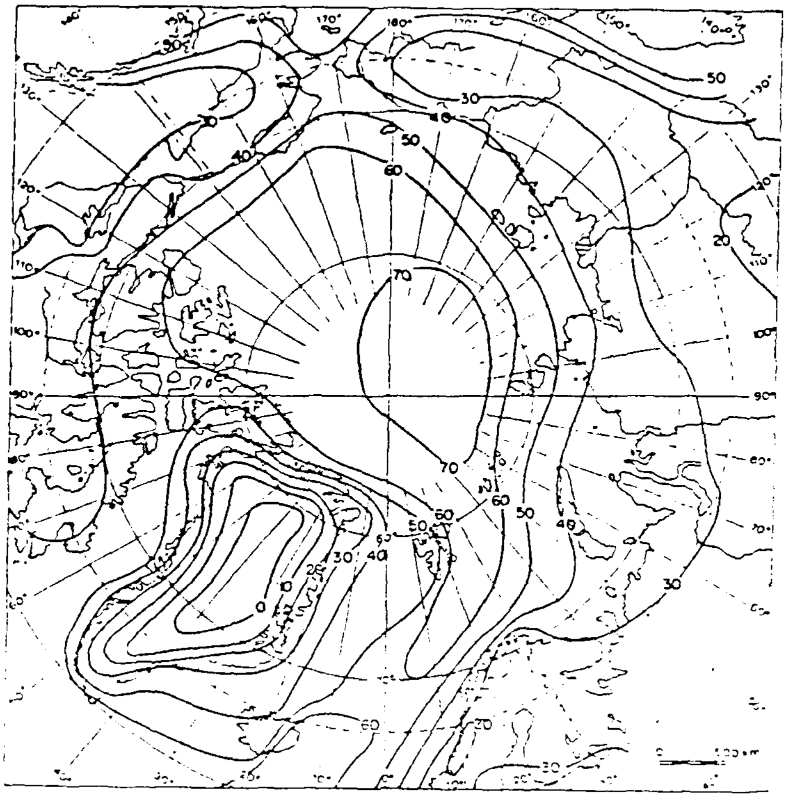
V. RAY NOONKESTER (NOSC)

OUTLINE OF PRESENTATION

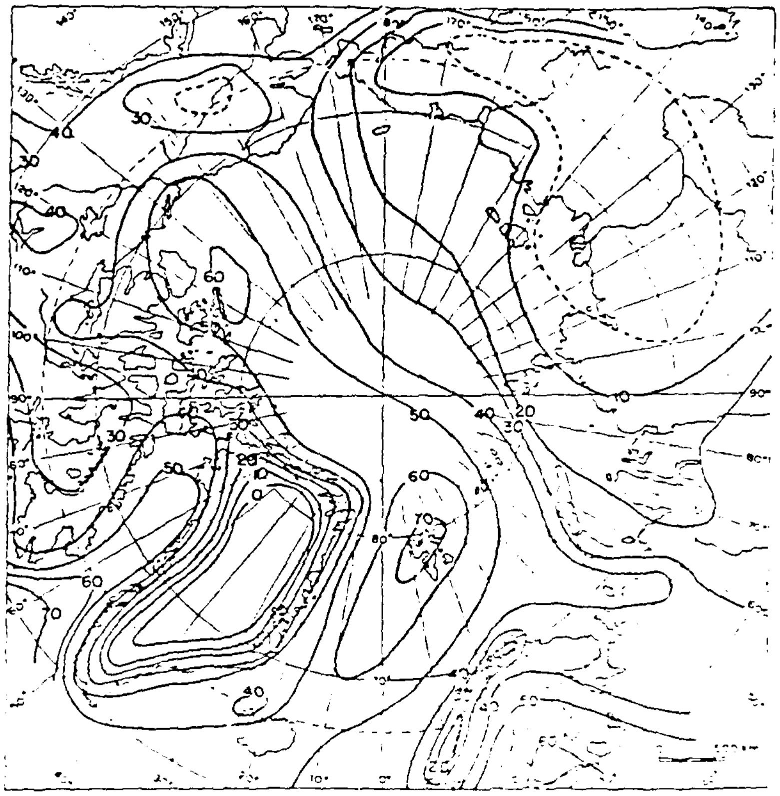
- OBSERVATIONS
- INTERPRETATION: ABOVE AND BELOW CLOUD BASE
- EXTINCTION COEFFICIENT PROFILES (3 λ's)
- HORIZONTAL VARIATIONS
- SUMMARY



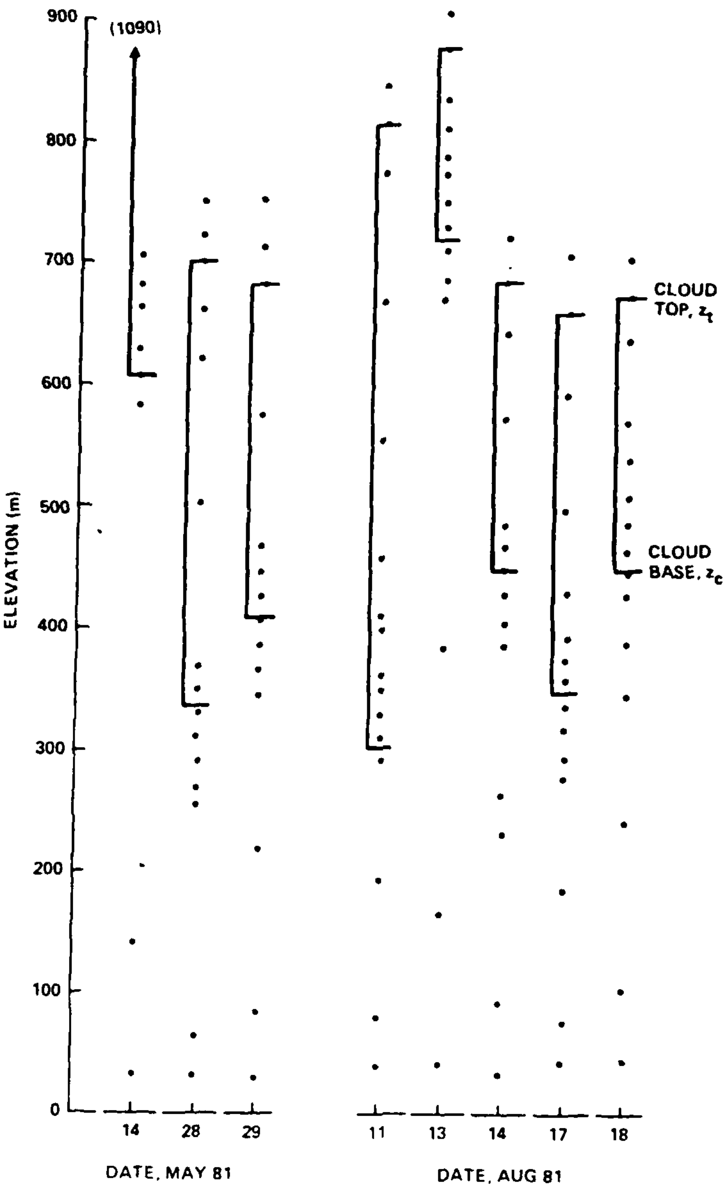
Example of extensive marine stratus cloud deck.



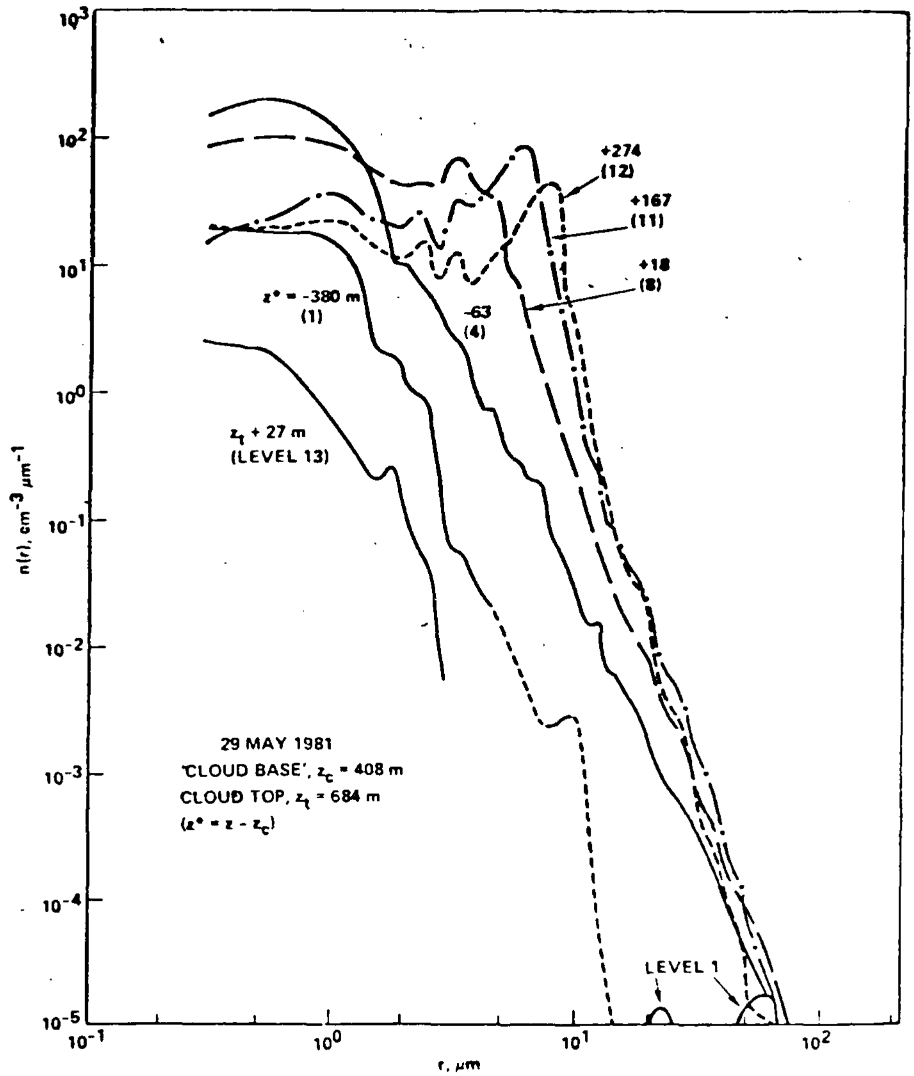
Frequency (% time) stratus and stratocumulus is present over the Arctic regions during the summer months. Source: Climates of the Polar Regions, Vol. 14 of World Survey of Climatology, edited by S. Orvig.



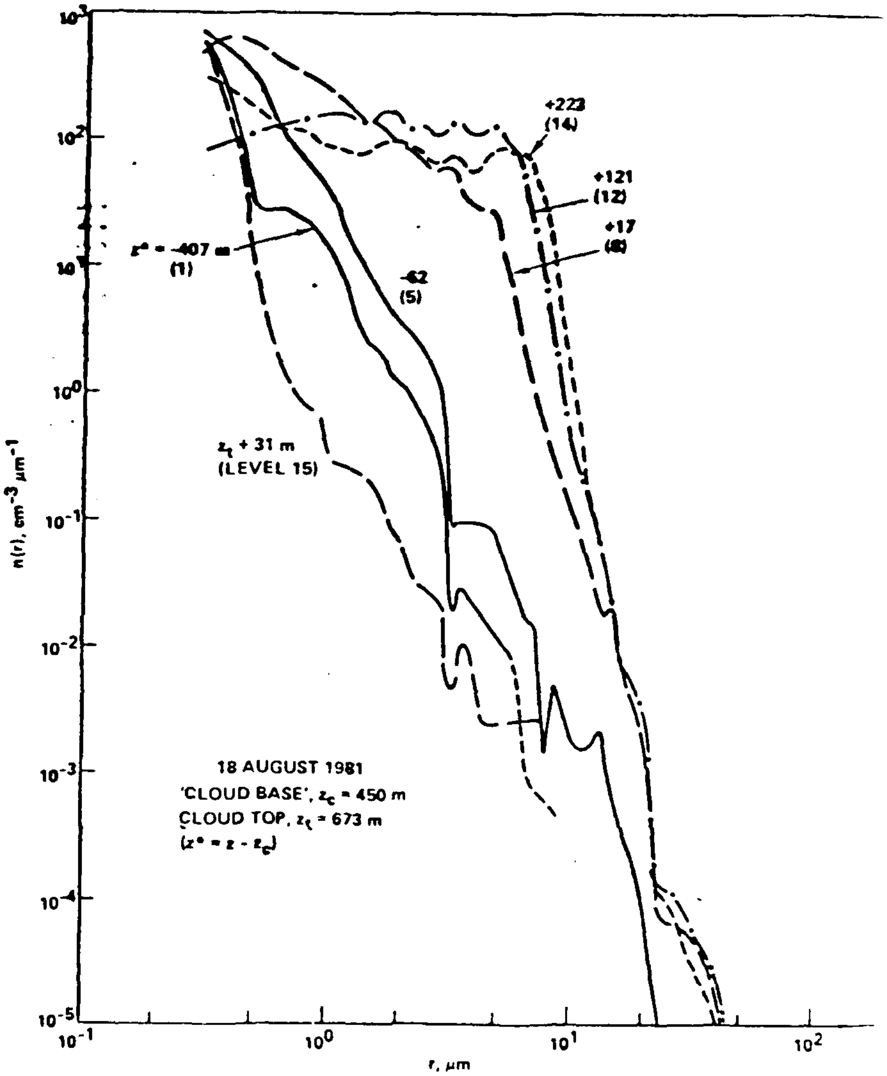
F, .uency (% time) stratus and stratocumulus is present over the Arctic regions during the winter months. Source: Climates of the Polar Regions, Vol. 14 of World Survey of Climatology, edited by S. Orvig.



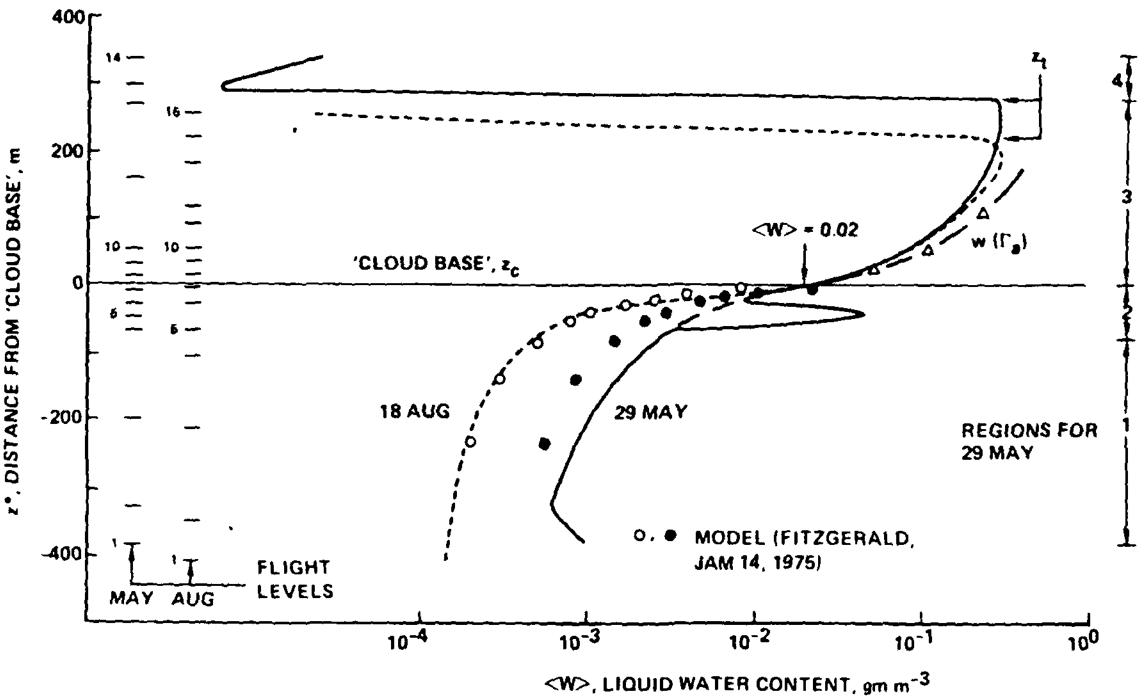
Elevations of the two minute horizontal runs (6.44 km) (dots) in the stratus layers 130 km SW San Diego and elevations of the cloud base z_c ($w = 0.02$ g m^{-3}) and top z_t.



Droplet spectra n(r) at selected levels and distances z^* from cloud base ($w = 0.02$ g m^{-3}) on 29 May 1981 when a 'marine' air mass was concluded to be present.



Droplet spectra n(r) at selected levels and distances z^* from cloud base ($w = 0.02$ g m^{-3}) on 18 August 1981 when a 'continental' air mass was concluded to be present.



Vertical profile of the liquid water content on 29 May and 18 Aug 81. $w(\Gamma_a)$ is the profile (average for 29 May and 18 Aug) expected for a moist adiabatic cooling of a rising air parcel. The large deviation at level 5 on 29 May is an atypical unexplained perturbation. The closed and open dots are predicted by Fitzgerald's model if $(MH_4)_2SO_4$ and NaCl, respectively, are the nuclei and if the relative humidity is 100% at the cloud base. The capability of the model to reproduce closely the profile $w(z^*)$ strongly suggests: (1) the layers are well mixed (adiabatic); (2) the saturation level is near the defined cloud base and (3) the nuclei on 29 May and 18 Aug are commensurate with nuclei expected in a marine and a continental air mass, respectively.

AEROSOL MODEL BELOW CLOUD BASE

BASIC EQUATIONS (FITZGERALD, JAM, V. 14, P. 1055, 1975)

- 'WET' (R) AND 'DRY' (R_d) AEROSOL RADII ARE RELATED

$$R = \alpha R_d^{\beta} \qquad \begin{cases} \alpha = F\,(\text{NUCLEI TYPE, RH}) \\ \beta = F\,(\text{RH}) \end{cases}$$

- 'DRY' AEROSOLS (NUCLEI) HAVE JUNGE DISTRIBUTION

$$N(R_d) = (\log e)\, C\, R_d^{-(\nu+1)}\ ;\ 0.1\mu M \le R_d \le 5\mu M$$

- 'WET' AEROSOLS HAVE DISTRIBUTION

$$N(R) = (\log e)\, \frac{C}{\beta}\, \alpha^{\frac{\nu}{\beta}}\, R^{-(\frac{\nu}{\beta}+1)}\ ;\ 81\% < R_i < 99.5\%$$

APPLICATION ON 18 AUGUST AND 29 MAY

- RH ACCORDING TO WELL-MIXED ADIABATIC LAYER
  - RH = 100% AT CLOUD BASE ($w = 0.02\ GM^{-3}$)
- NUCLEI PARAMETER α FOR
  - $(NH_4)_2SO_4$: 18 AUGUST
  - NACL: 29 AUGUST
- C, ν FROM LOW-LEVEL $N(R)$
- INTEGRATE $N(R)$ FROM $R = 1\mu M$ TO $20\mu M$ FOR w

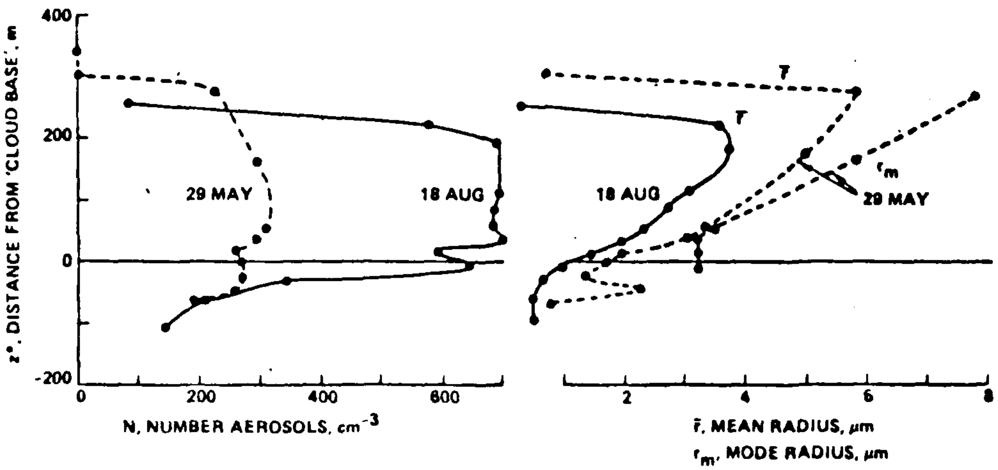
AEROSOL STRUCTURE ABOVE CLOUD BASE

'CLASSICAL' IN-CLOUD AEROSOL MODELS

- SUPPORTIVE MODELS: NEIBURGER AND CHEIN, GEOPHYS. MON. NO. 5, AGU, 1960; FITZGERALD, JAS, V. 41, P. 1044, 1975.
- GENERAL FEATURES OF MODELS
  - ADIABATIC COOLING OF RISING AIR PARCELS CARRYING CCN THROUGH SATURATION LEVEL
  - ACTIVATED PARTICLES GROW IN SUPERSATURATED AIR FORMING A MODE IN N(R) AND MODE RADIUS INCREASES WITH ELEVATION WHEN NUCLEI LIKE NACL ARE INVOLVED

COMPARISON WITH DATA ON 29 MAY AND 18 AUGUST

- DATA ON 29 MAY FOLLOWS CLASSICAL MODEL
- DATA ON 18 AUGUST APPROXIMATES CLASSICAL MODEL EXCEPT A DISTINCT MODE IS ABSENT.
  - MANY SMALL AEROSOLS ON 18 AUGUST.



In-cloud profiles demonstrates differences expected for marine (29 May) and continental (18 Aug) air masses.

EXTINCTION COEFFICIENTS

'TRUE' EXTINCTION COEFFICIENT

$$K_1(\lambda) = \int Q\left(\frac{2\pi R}{\lambda}, M\right) R^2 N(R)DR$$

APPROXIMATE EXTINCTION COEFFICIENTS

- SMALL-λ APPROXIMATION, $Q \simeq 2$

  $K_2 = 2A$

  - IF THE EQUIVALENT RADIUS R_E IS INTRODUCED

  $$R_E = \frac{\int R^3 N(R)\, DR}{\int R^2 N(R)\, DR} = \frac{3}{4\rho_W} \frac{W}{A}$$

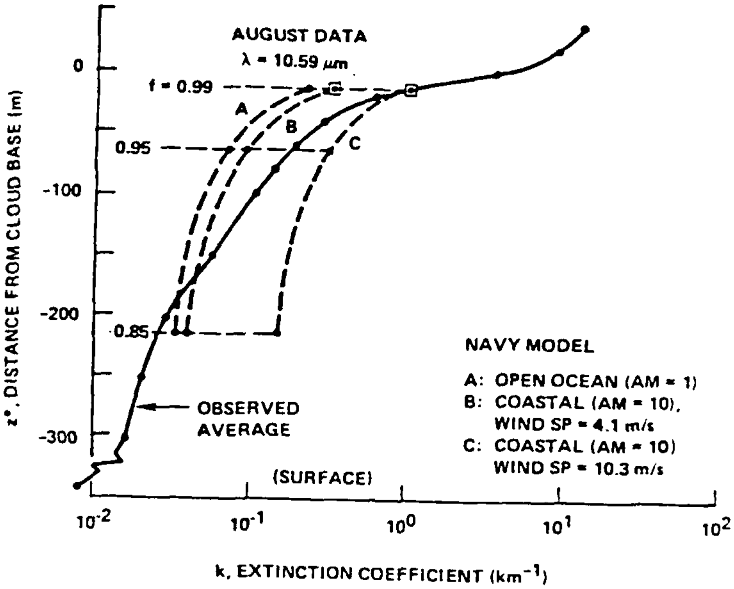
  $$K_2 = \frac{3}{2\rho_W} \frac{W}{R_E}$$

- LARGE-λ APPROXIMATION, $Q \simeq C(2\pi R/\lambda)$

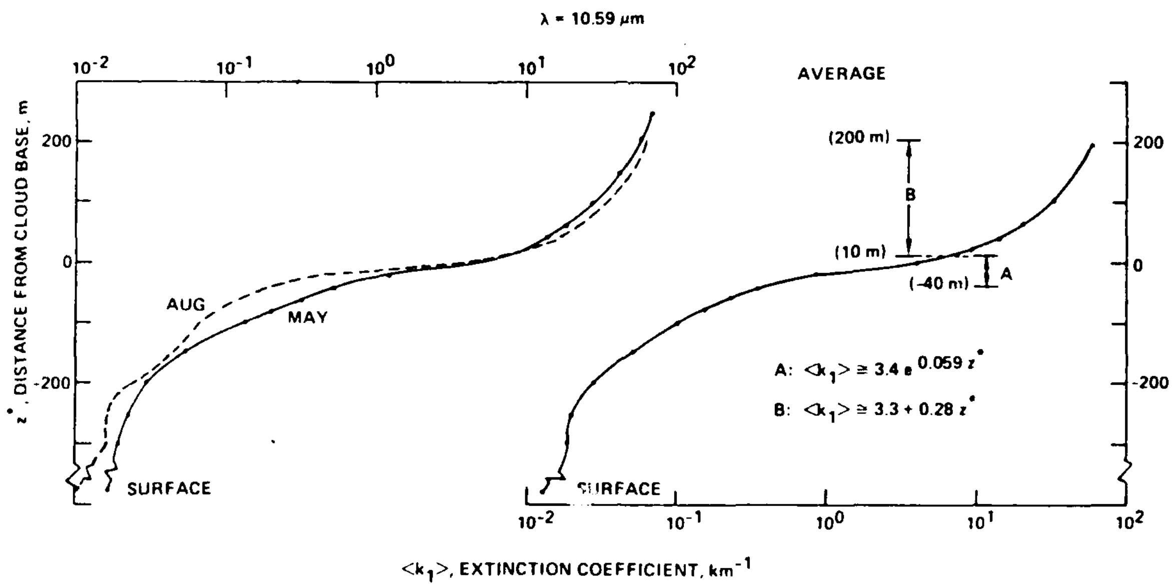
  $$K_3 = \frac{3C\pi}{2\rho_W} W$$

- EMPIRICAL RELATION

  $K_4 = AW^B$



Profile of the average of the August data and profiles by the Navy model. No combination of parameters for the Navy model can reproduce the large gradient below the cloud at λ = 10.59 μm. The results were similar at λ's of 0.53 and 3.75 μm.



Profiles for the May and August days and for all days combined at $\lambda = 10.59\ \mu m$.

Optical Depth τ_i	Wavelength, λ (μm)		
	0.53	3.75	10.59
	$20\ m \leq z^* \leq 200\ m$		
τ_1	8.0	9.7	6.1
τ_2	7.0	7.0	–
τ_3	–	25.2	5.9
τ_4	8.2	9.9	6.3
	$-40\ m \leq z^* \leq 10\ m$		
τ_1	0.30	0.32	0.10
τ_2	0.19	0.19	–
τ_3	–	0.62	0.15
τ_4	0.32	0.28	0.11

Optical depths for various extinction coefficients and regions of the average cloud layer. The subscripts are associated with the following extinction coefficients:

$$k_1 = \pi \int Qr^2\ n(r)\ dr \quad (\text{'true'})$$

$$k_2 = 2A \quad (\text{small } \lambda)$$

$$k_3 = \frac{3\pi C}{2\rho_w \lambda} w \quad (\text{large } \lambda)$$

$$k_4 = aw^b \quad (\text{empirical})$$

These τs indicate that k_4 is a superior approximation to k_1 for 3 λs.

HORIZONTAL VARIABILITY OF κ_1

RELATIVE VARIABILITY

- DEFINED TO BE

  $$\frac{\sigma_{\kappa_1}}{\langle \kappa_1 \rangle}\ ; \quad \kappa_1 \text{ FOR } \lambda = 0.53,\ 3.75,\ 10.59\mu m$$

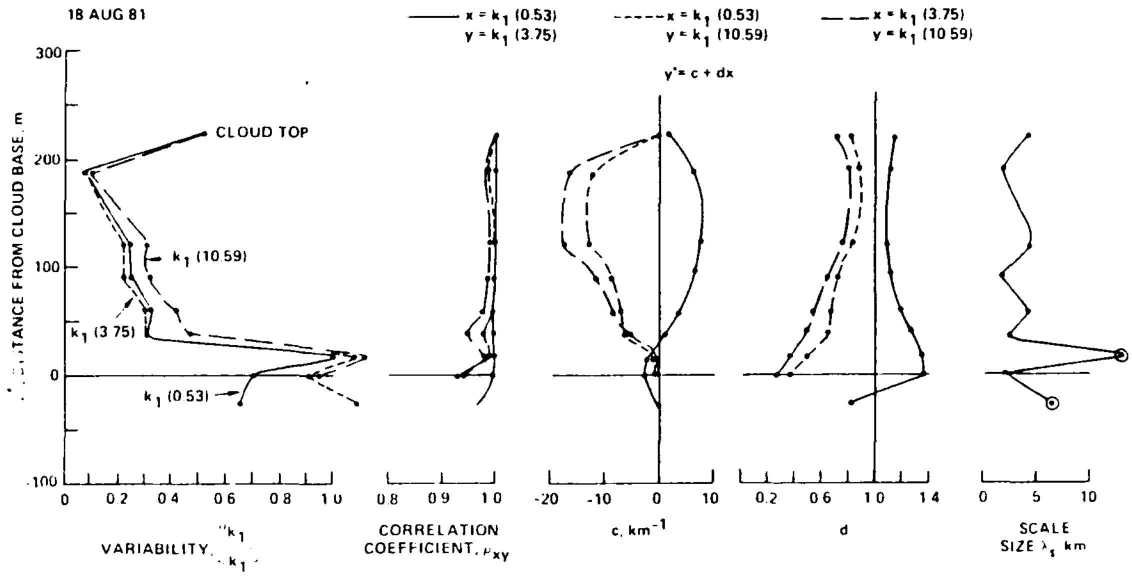
  $N = 15$ (429m FOR EACH $N(R)$)

APTIFICIAL (INSTRUMENTAL) VARIABILITY

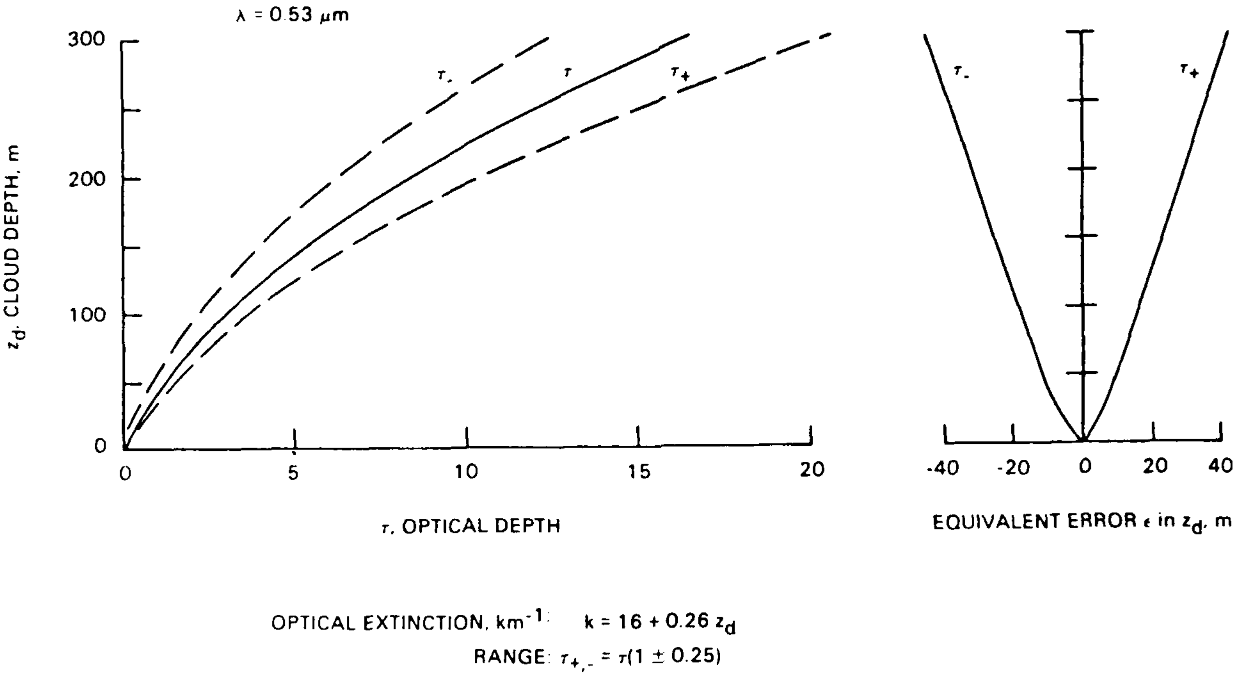
- σ_{κ_1} INCREASES WHEN THE DROPLET COUNT N IS SMALL IN A REGION OF $N(R)$ CONTROLLING κ_1
  - $N \lesssim 60$ FOR ASSP-100 ($0.23\mu m \le R \le 14.7\mu m$)
  - $N \lesssim 15$ FOR OAP-200 ($14.2\mu m \le R \le 155\mu m$)
- ARTIFICIAL VARIABILITY EXISTED AT MOST LEVELS UP TO ABOUT 60m BELOW CLOUD BASE.

TREND/SCALE SIZE

- TRENDS ARE PRESENT ALONG A HORIZONTAL RUN WHEN THE SCALE SIZE $\lambda_s > 6.44$km, THE RUN LENGTH.
  - σ_κ IS MEANINGLESS WHEN $\lambda_s > 6.44$km.
- λ_s WAS ESTIMATED TO BE 3km USING THE NUMBER OF DEVIATIONS OF κ_1 FROM $\langle \kappa_1 \rangle$ ALONG A RUN.
- $\lambda_s = 3$km IS APPROPRIATE FOR MODERATE CONVECTION (FITZJARRALD, JAM, V. 17, P. 21[illegible]).

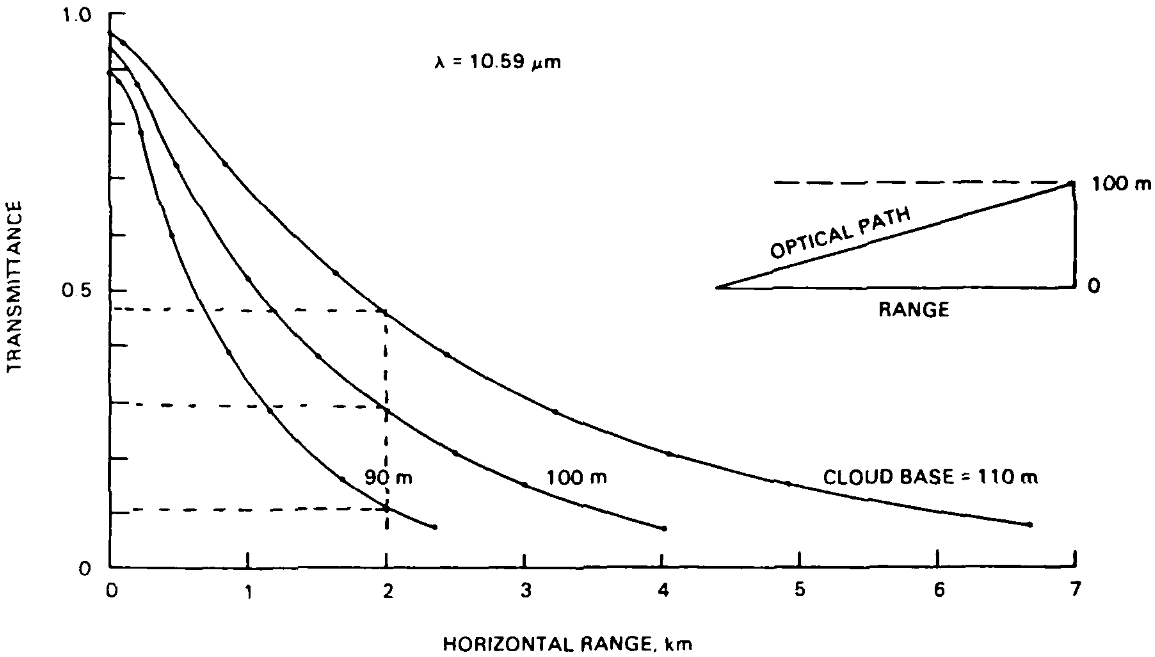


Profiles of parameters describing the horizontal variability and interrelationships for the extinction coefficients on 18 Aug. The average variability was about 25% in the cloud for 29 May and 18 Aug.



Left: Example illustrating the range in τ at a λ = 0.53 μm if k_1 varied by ±25% from the true τ along a vertical path as a function of cloud depth (k_1 for average of May and Aug data). The indicated range would be expected if the increases and decreases in the cloud occurred simultaneously (in phase) along the vertical. This maximum range would be repeated every 3 km, the horizontal scale size indicated by the data.

Right: The equivalent error in estimating the cloud depth to give the range of τs for the 25% variability.



Example illustrating the error in transmittance along a path from the surface to cloud base as a function of range for λ = 10.59 μm. Thus, if the true cloud base is at z = 100 m at a range of 2 km, the transmittance would be calculated (for May and Aug data combined) to be 0.3, whereas if the cloud base were incorrectly estimated to be 10 m above or below the true cloud base, the transmittance would be calculated to be 0.46 and 0.1 respectively

REPRESENTATIVE MEASUREMENTS

SAMPLE LENGTH L IN TURBULENT LAYER

- WHEN TURBULENCE IS THE ONLY SOURCE OF VARIATIONS ALONG A RUN (LUMLEY AND PANOFSKY, THE STRUCTURE OF ATMOS. TURB., 1964).

  $L \simeq 2\ell \left(\frac{\sigma_K / \langle K \rangle}{\epsilon}\right)^2$

  - ℓ SCALES WITH MIXED LAYER DEPTH, Z_t
  - ϵ IS ACCEPTABLE RELATIVE ERROR

- L AVERAGED 36 KM FOR ϵ=10% ON 29 MAY AND 18 AUGUST

  - $L \simeq$ 2 KM ABOUT Z_t -40 KM

  - AN EXCESSIVE AMOUNT OF TIME WOULD BE REQUIRED TO USE $L \simeq$ 30-40 KM WHEN TEMPORAL CHANGES WOULD OCCUR AND MESOSCALE VARIATIONS MIGHT BE INCLUDED.

SUMMARY

- A PROTOTYPE DROPLET-EXTINCTION MODEL HAS BEEN DEVELOPED FOR MARINE STRATUS LAYERS, AN IMPORTANT EO ENVIRONMENT
  - THE MAJOR INPUT IS THE ELEVATION OF SATURATION
  - THE "AIR MASS" CAN BE INCLUDED IF KNOWN
  - EFFECTS OF LOCAL, LIGHT WINDS WERE NOT EVIDENT
- HORIZONTAL VARIABILITY CAN BE APPRECIABLE
  - IS MINIMUM IN MID-CLOUD
  - NECESSITATES LONG SAMPLING PATH

INTERACTIVE SOFTWARE FOR
CALCULATING CLOUD-FREE INTERVALS

Lt Col Vernon Bliss
Air Force Weapons Laboratory

INTERACTIVE SOFTWARE
FOR
CALCULATING CLOUD-FREE INTERVALS

27 JUN 84

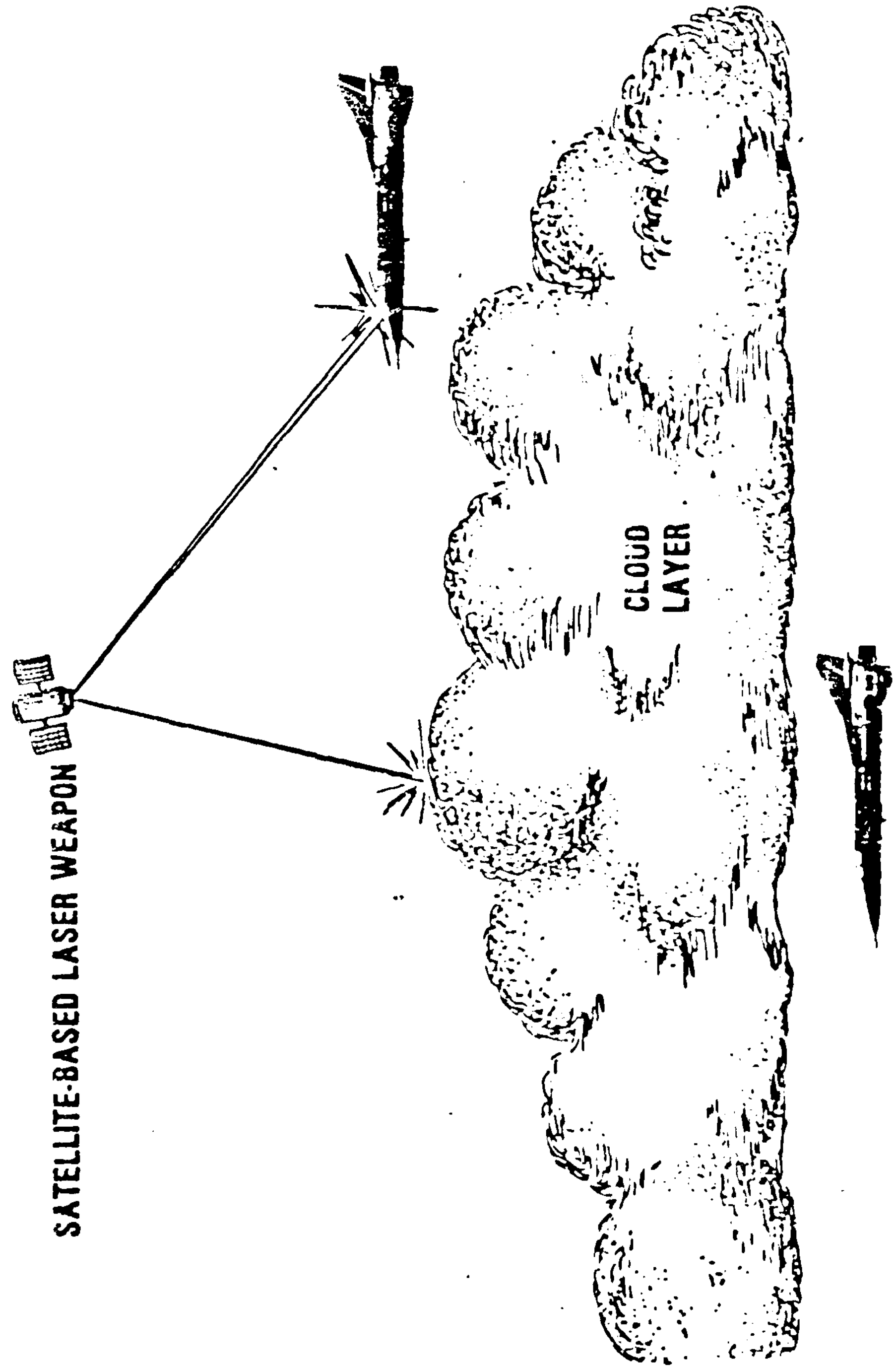
AFWL/WE

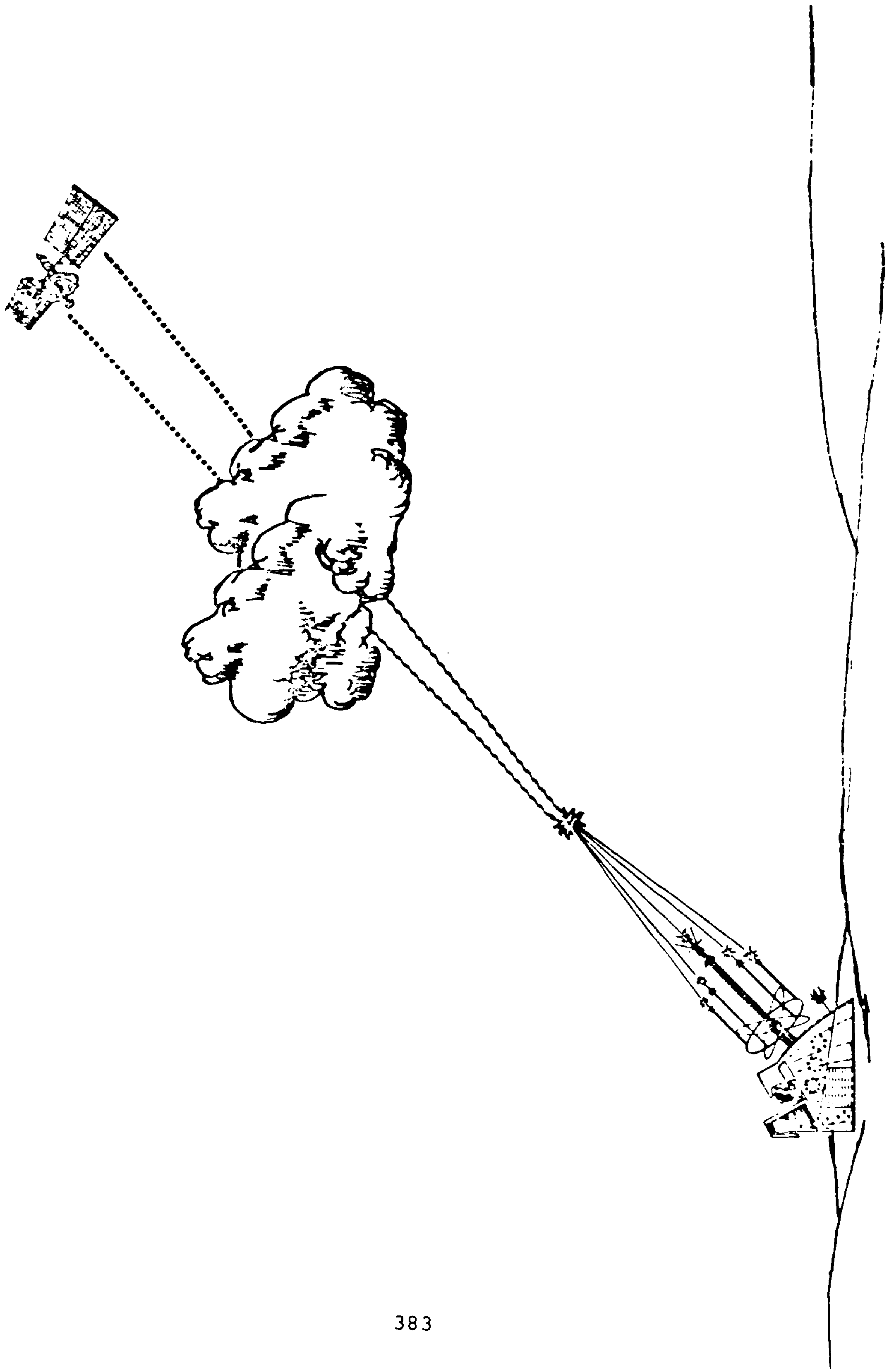
LT COL BLISS

A FORTRAN program that estimates the probability of cloud-free intervals (CFI) has been developed as an aid in assessing the vulnerability of aircraft to space-based lasers. The software interactively leads the analyst through the definition of the aircraft path (anywhere in the Northern Hemisphere) and other parameters of the problem and calculates and displays the results in real time. This permits the analyst quickly to analyse the sensitivity of cloud blockage effects to such variables as look angle, season of year, geographic region, path length, altitude of target, and length of cloud-free interval needed for mission success. Incorporating Monte-Carlo techniques, the software simulates flying along the defined path many times while looking, on each flight, for the occurrence of cloud-free intervals greater than or equal to a length of interest. The number of flights during which at least one such occurrence is detected divided by the total number of flights becomes the CFI probability for that particular set of input parameters. The program's technical basis rests upon a probability distribution model relating cloud-free-line-of-sight to cloud-free interval. This model and some other aspects of the software, such as the treatment of spatial correlation of cloudiness, were derived from the earlier work of Malick and Allen at the Stanford Research Institute.

PREVIEW

* SCENARIOS
* SOME BACKGROUND
* MALICK AND ALLEN
* AFWL INTERACTIVE CFI SOFTWARE
* SOME RESULTS
* TIME TO DISTANCE
* FURTHER POSSIBILITIES
* CAVEATS, CONCLUSIONS


SATELLITE-BASED LASER WEAPON
CLOUD LAYER



CLOUD-FREE-LINE-OF-SIGHT

Static--

point in time & space

PCFLOS(Lund & Shanklin)

Dynamic

finite time & space intervals

PCFI(Malick & Allen, SRI)

BASIC SRI HYPOTHESES

Alternating clear & cloudy intervals

Exponential distributions for lengths

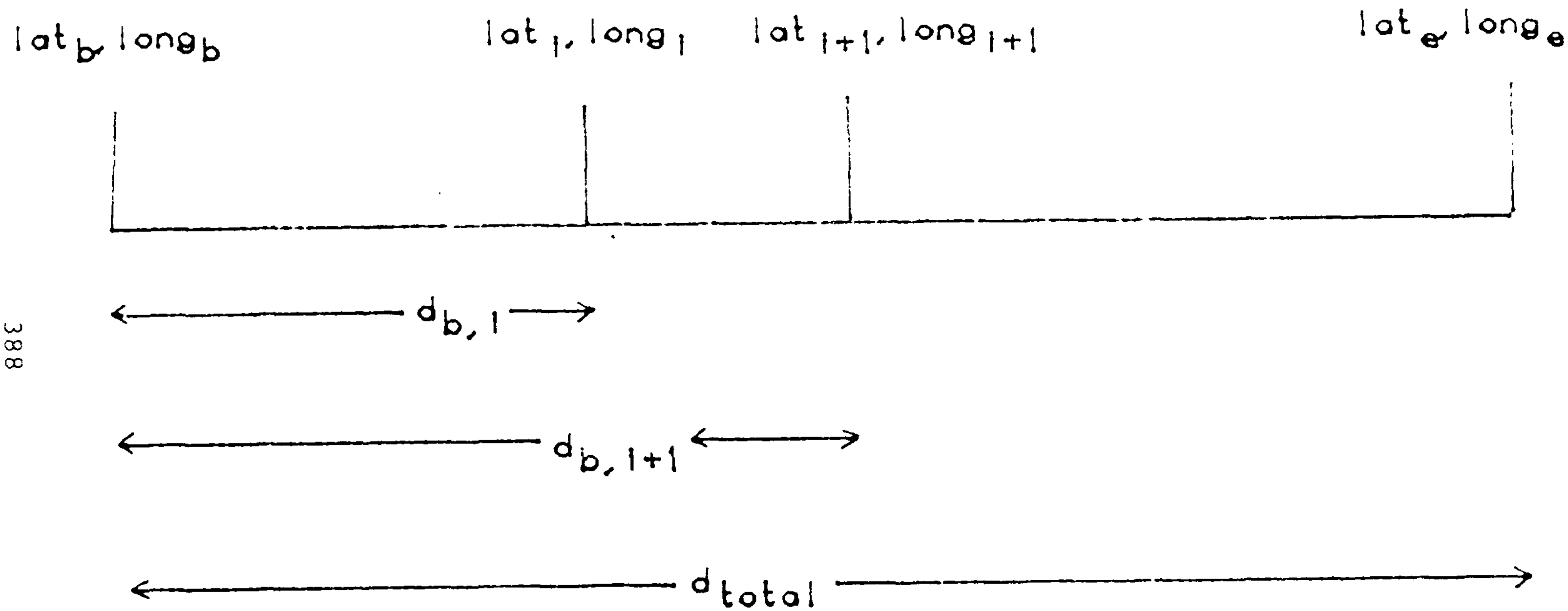
Mean intervals function PCFLOS

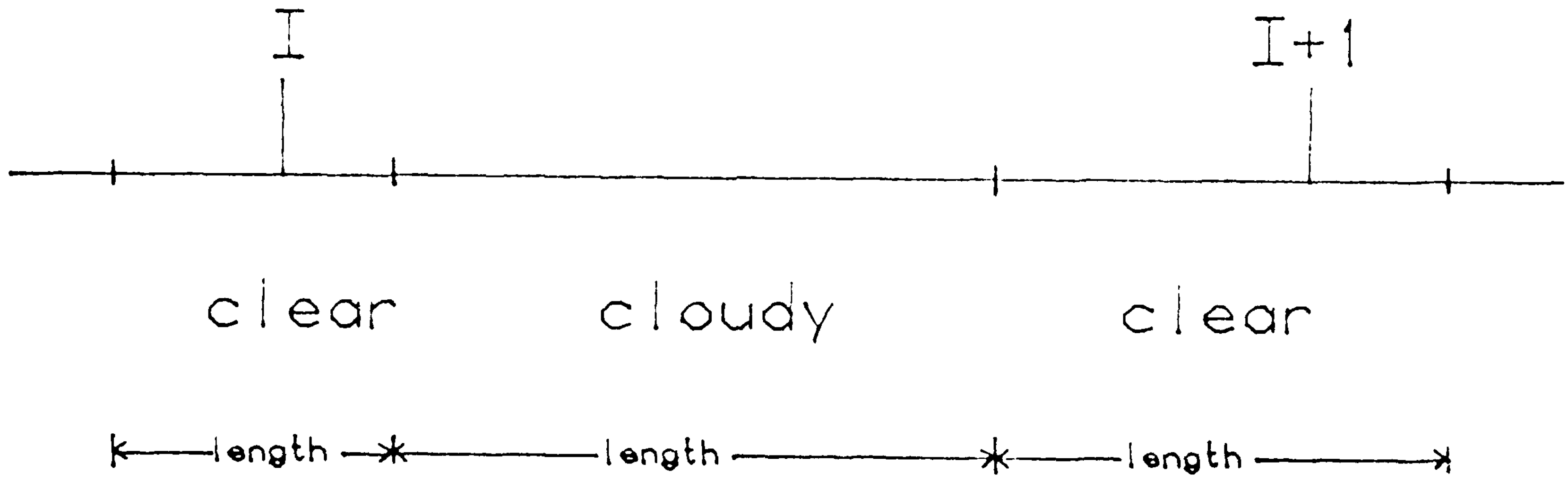
AFWL/WE MODEL

* Based upon SRI ideas and cloud data base
* Any track and interval combinations anywhere in N Hemisphere
* Less analytical modelling than SRI
* Interactive

INITIALIZATION

1. DEFINE PATH AND INTERMEDIATE POINTS (PROGRAM CALCULATES GREAT CIRCLE DISTANCE ALONG PATH)
2. SELECT SEASON OF YEAR AND ELEVATION ANGLE
3. SELECT WEATHER DATA TO BE USED ALONG VARIOUS PATH SEGMENTS
4. DEFINE TARGET HEIGHT TO BE USED ALONG ARIOUS PATH SEGMENTS
5. DEFINE LENGTHS OF C F I FOR WHICH PROBABILITIES DESIRED
6. SELECT NUMBER OF MONTE CARLO ITERATIONS
7. SET CLOUD CORRELATION SWITCH


$lat_b, long_b$
$lat_1, long_1$
$lat_{1+1}, long_{1+1}$
$lat_e, long_e$
$d_{b,1}$
$d_{b,1+1}$
d_{total}


I
I+1
clear
cloudy
clear
length
length
length

MONTE CARLO ITERATION SEQUENCE

1 Ø DISTANCE ALONG PATH, Ø EVENT SWITCHES

2 ALTERNATE CLOUDY / CLEAR INTERVALS

3 DRAW CLOUD COVER FROM FREQUENCY DISTRIBUTION

4 CORRELATE CLOUD COVER (SPATIALLY)

5 CALCULATE P C F L O S

6 CALCULATE MEAN RUN LENGTH FROM P C F L O S

7 DRAW RUN LENGTH FROM EXPONENTIAL DISTRIBUTION

8 ADD RUN LENGTH TO DISTANCE COVERED

9 SET EVENT SWITCH TO 1 IF RUN LENGTH MEETS EVENT SUCCESS CRITERIA

NO — END OF PATH?

YES

10 ADD SWITCH SETTINGS TO EVENT COUNTERS

NO — END OF ITERATIONS?

YES

11 COMPUTE EVENT PROBABILITY

(#ITERATIONS IN WHICH EVENT OCCURRED)/(TOTAL #ITERATIONS)

SOME RESULTS

JAN , 30° ELEVATION ANGLE, LOCATION X

MONTE CARLO ITERATIONS = 1000

INTERVAL LENGTH (KM)	TRACK (KM)	10	30	100	300
	S R I				
10		.10	.10	.35	.47
	A F W L (NO CORRELATION)				
		.15	.24	.39	.54
	A F W L (CORRELATION)				
10		.19	.24	.45	.73

COMPARISON WITH P C F L O S

JAN, 30° ELEVATION ANGLE, LOCATION X

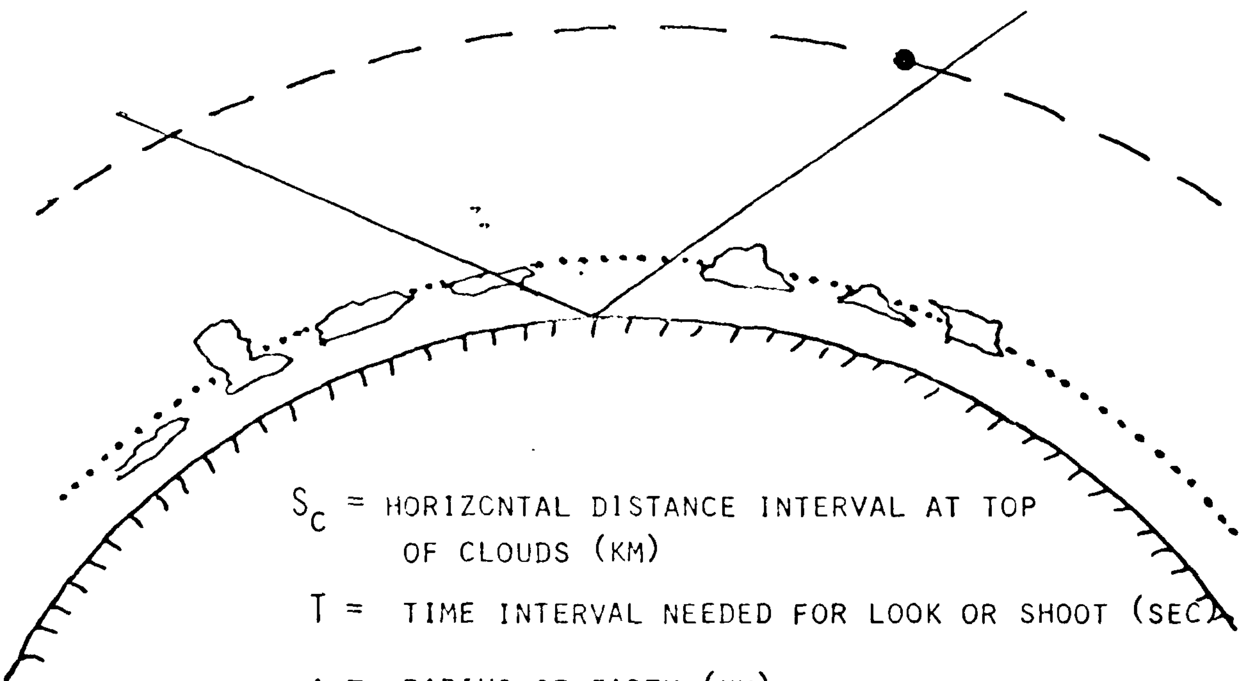
CLIMATOLOGICAL P C F L O S = .33

INTERVAL (= TRACK)(KM)	P(NO CORRELATION)	P(CORRELATION)
.01	.30	.32
.1	.32	.33
1	.28	.30
3	.22	.30
10	.15	.17
30	.06	.06
100	.06	.02
300	.04	.01

GROUND - TO - SPACE

(CONVERSION OF TIME TO DISTANCE INTERVALS)

$$S_C \sim \frac{T}{\sqrt{A + H_S}} \left(1.99 \times 10^{7}\right) \frac{H_C}{H_S}$$



S_C = HORIZONTAL DISTANCE INTERVAL AT TOP OF CLOUDS (KM)

T = TIME INTERVAL NEEDED FOR LOOK OR SHOOT (SEC)

A = RADIUS OF EARTH (KM)

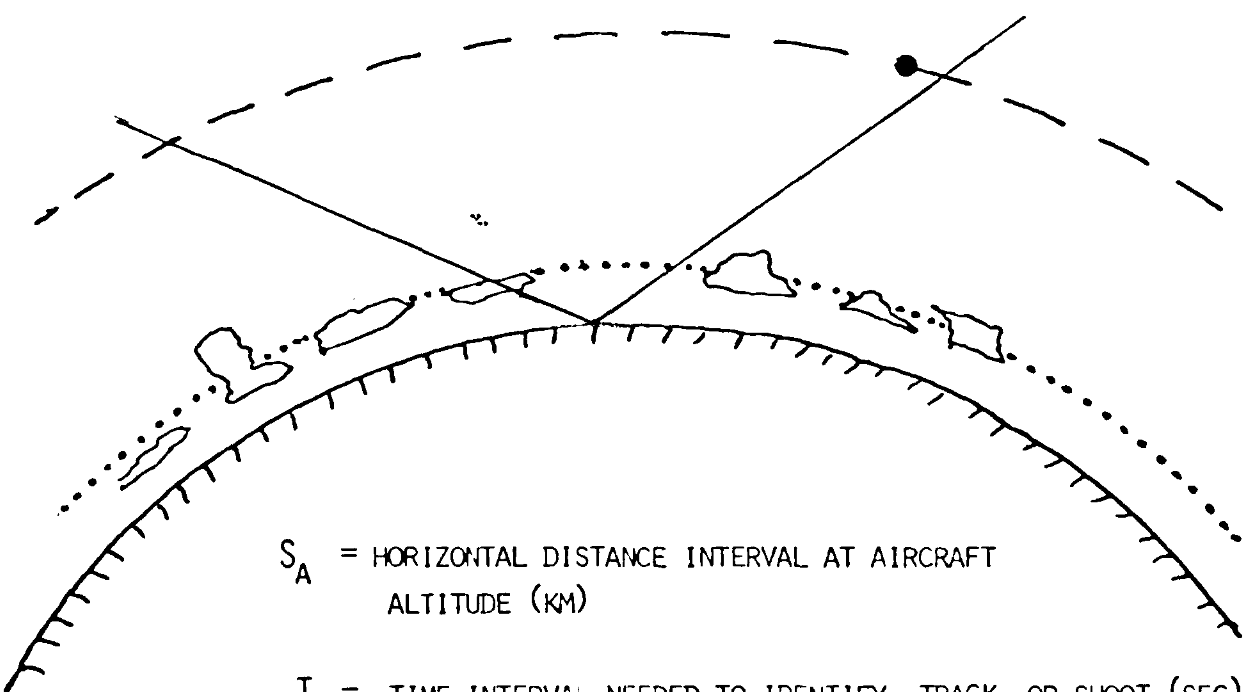
H_S = ALTITUDE OF SATELLITE (KM)

H_C = ALTITUDE OF TOP OF CLOUDS (KM)

SPACE - TO -- AIRCRAFT

(CONVERSION OF TIME TO DISTANCE INTERVALS)

$$S_A = VT$$



S_A = HORIZONTAL DISTANCE INTERVAL AT AIRCRAFT ALTITUDE (KM)

T = TIME INTERVAL NEEDED TO IDENTIFY, TRACK, OR SHOOT (SEC)

V = VELOCITY OF AIRCRAFT (KM/SEC)

FURTHER POSSIBILITIES

* BELLS AND WHISTLES

  --- CURRENT SOFTWARE INTERACTIVE BUT NOT SUPER FRIENDLY

  --- NEED TO ALLOW OUTSIDE INPUT OF CLOUD FREQUENCY DISTRIBUTIONS

* EVENT MODIFICATIONS

  --- STRAIGHT --- FORWARD CHANGES, CAN COUNT EVENTS WHATEVER THE COMBINATION OF CLEAR / CLOUDY LENGTHS

CONCLUSIONS & CAVEATS

1. SOFTWARE MORE USEFUL FOR RELATIVE RATHER THAN ABSOLUTE EVALUATION OF VARIOUS SYSTEM/CLOUD BLOCKAGE SCENARIOS

2. RELATIONSHIP BETWEEN CFLOS & FREQUENCY DISTRIBUTION OF CLEAR/CLOUDY INTERVALS SHOULD BE REVALIDATED.

3. MODEL AS A WHOLE SHOULD BE VALIDATED.

4. USERS SHOULD BE JUDICIOUS IN USING THIS OR ANY OTHER CLOUD MODEL -- NEED TO UNDERSTAND LIMITATIONS AND ASSUMPTIONS.

3-D CLOUD SIMULATION USING THE SAWTOOTH MODEL

Irving I. Gringorten
Air Force Geophysics Laboratory

3D - BSW - MODEL

GOALS

A. TO PRODUCE CLOUD COVER STOCHASTICALLY TO RESEMBLE CLOUDS

B. TO SIMULATE DISTRIBUTION OF CLOUD SIZE AND SEPARATION

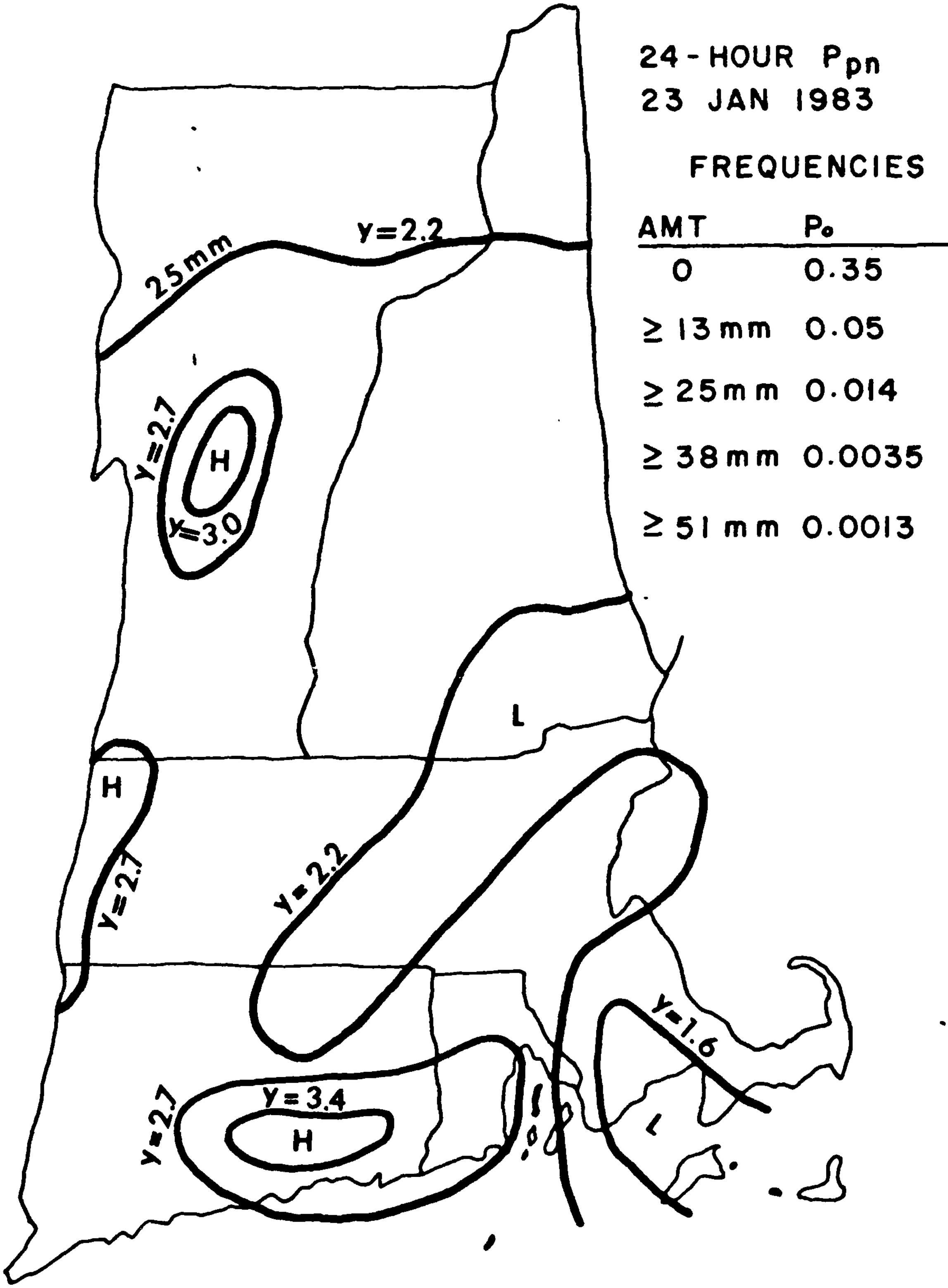
C. TO SIMULATE FRACTAL STRUCTURE

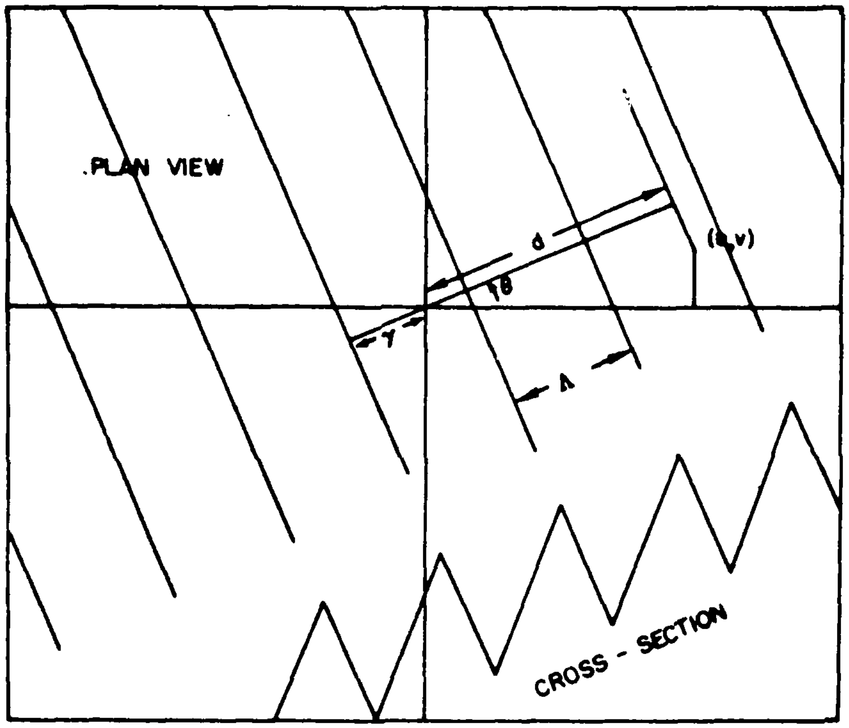
D. TO SIMULATE VERTICAL STRUCTURE AND DISTRIBUTION

24-HOUR P_{pn}
23 JAN 1983

FREQUENCIES

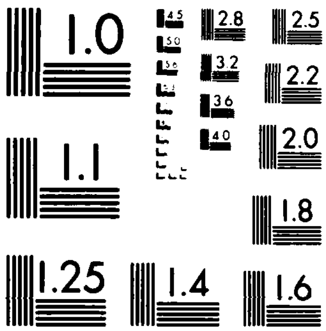
AMT	P_o	y
0	0.35	0.4
≥ 13 mm	0.05	1.6
≥ 25 mm	0.014	2.2
≥ 38 mm	0.0035	2.7
≥ 51 mm	0.0013	3.0




PLAN VIEW
d
θ
γ
Λ
CROSS - SECTION

AD-A152 735 PRESENTATIONS AT THE TRI-SERVICE CLOUD MODELING WORKSHOP (2ND) HELD AT TH..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA E BAUER AUG 84 IDA-M-9-VOL-1 5/7

UNCLASSIFIED IDA/HQ-84-28971 MDA903-84-C-0031 F/G 4/2 NL


1.0
4.5
5.0
5.6
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

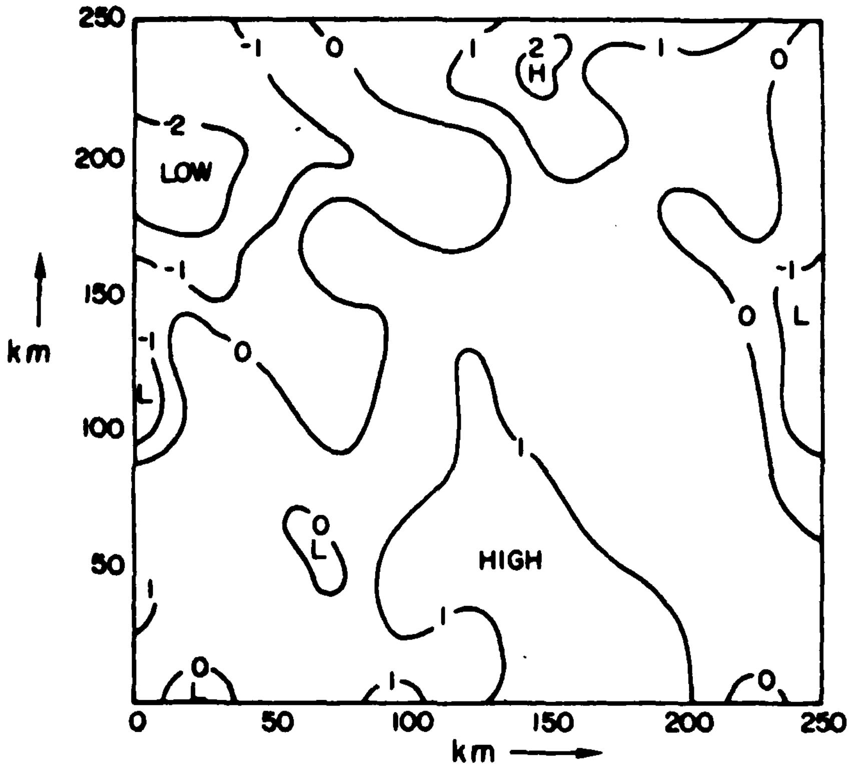
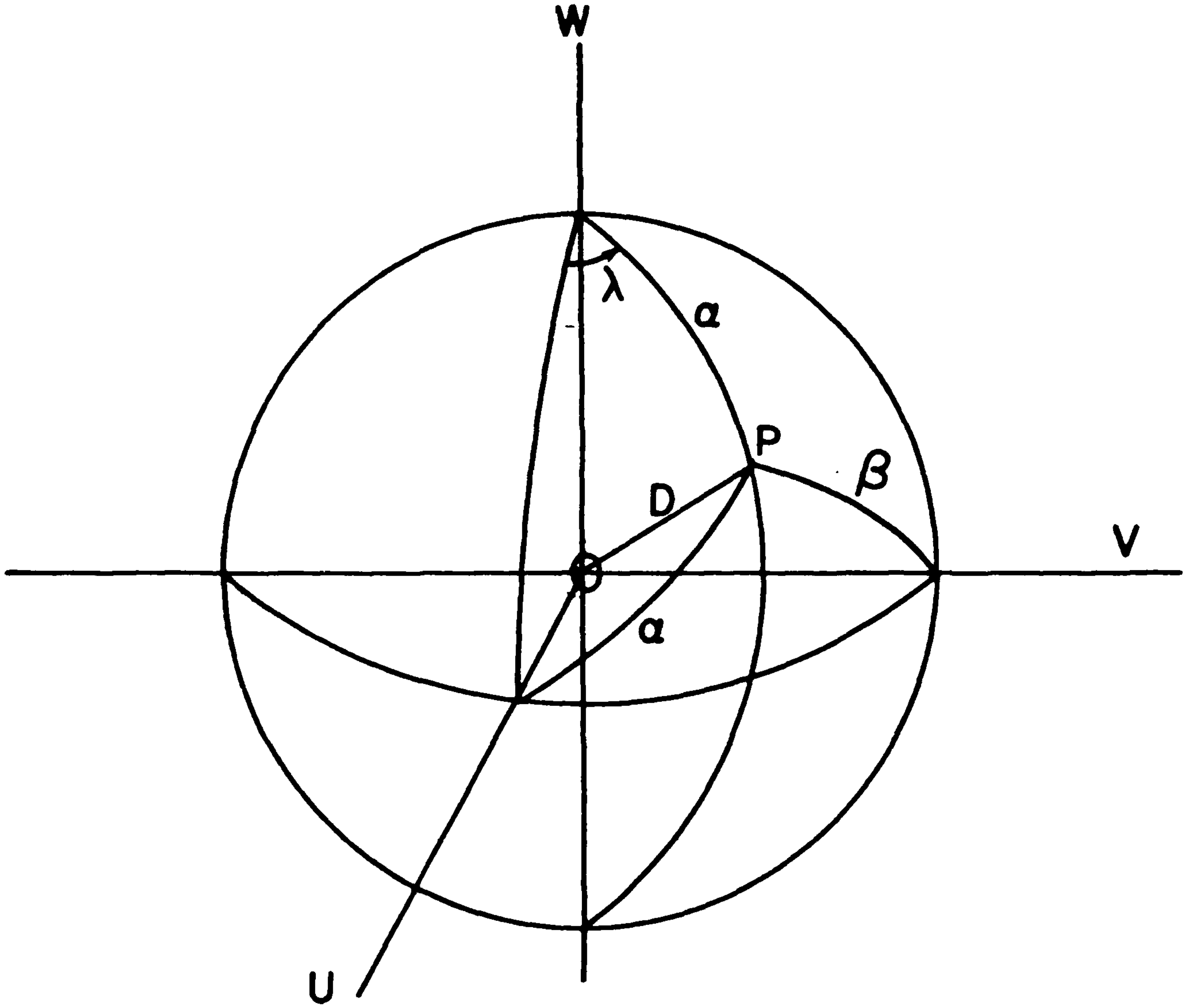


Fig. 10. Example of horizontal field generated stochastically by the BSW-model.



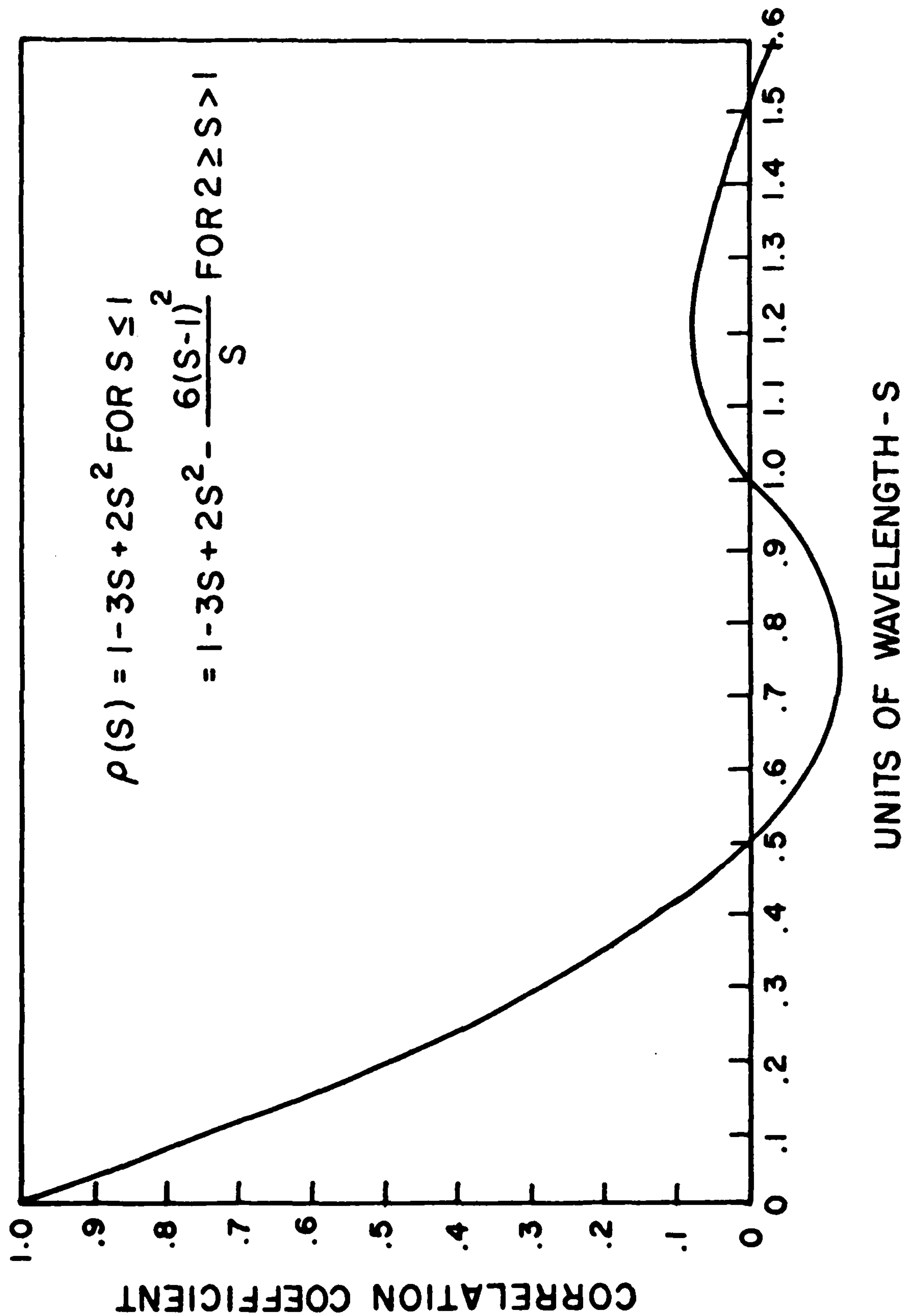
IN 3D - MODELING:

$$\cos^2\alpha + \cos^2\beta + \cos^2\gamma = 1$$

CHOOSE AT RANDOM; $\cos\gamma$, λ, h

WAVE HEIGHT = FRA(h + D)

$$D = U \cdot \cos\alpha + v \cdot \cos\beta + w \cdot \cos\gamma$$



ρ(S) = 1-3S+2S² FOR S ≤ 1
= 1-3S+2S² - 6(S-1)²/S FOR 2 ≥ S > 1
UNITS OF WAVELENGTH - S
CORRELATION COEFFICIENT
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6

FOR FRACTALS

$$y_F(u,v,w) = \rho_R \cdot y_{\Lambda_0}(u,v,w) + \sqrt{1-\rho_R^2} \cdot y_{\Lambda_1}(u,v,w)$$

FOR TIME CHANGE

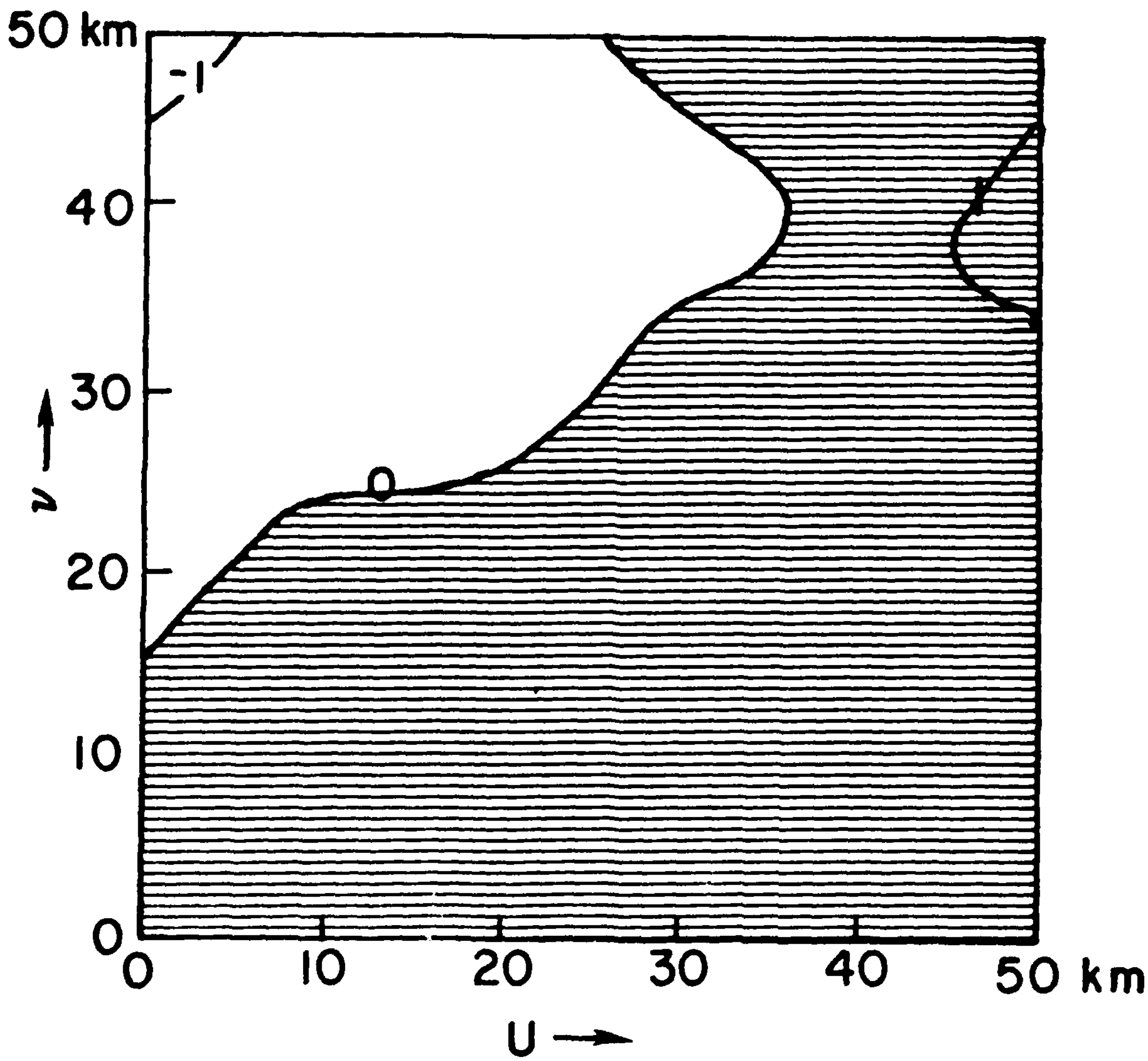
$$y_t(u,v,w) = \rho_{\delta t} \cdot y_{t-\delta t}(u,v,w) + \sqrt{1-\rho_{\delta t}^2} \cdot \eta_t(u,v,w)$$

$$\rho_{\delta t} = \exp\left(-\frac{\delta t}{\tau}\right)$$

A STOCHASTIC SNAPSHOT
($P_o = 0.5$)

WAVELENGTH : 256 km
(No FRACTALS)

AREA : $(50\,km)^2$, SKY-DOME SIZE



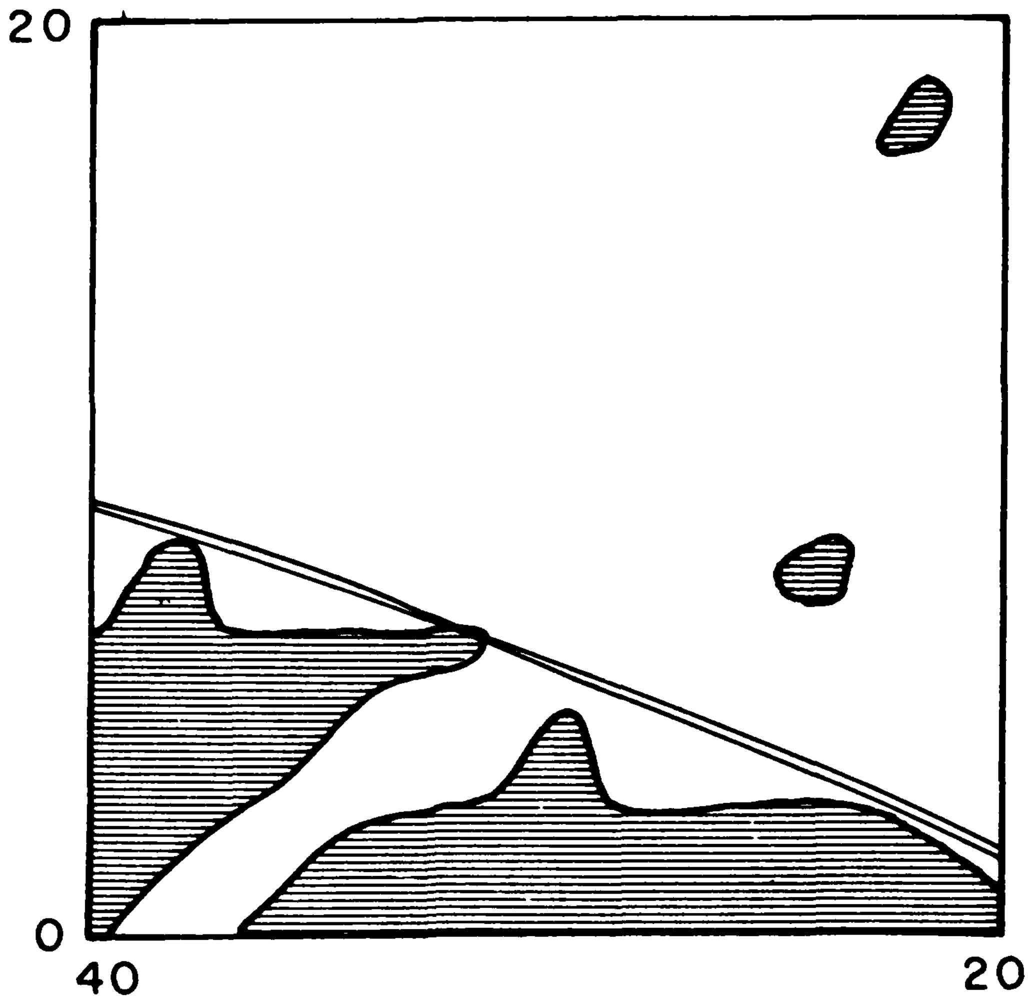
AREA : APPROXIMATELY SKY-DOME SIZE

BASIC WAVELENGTH: 742 km

FRACTAL WAVELENGTH: 7.42 km

CORRELATION: 0.95

AREA: $(20\ km)^2$



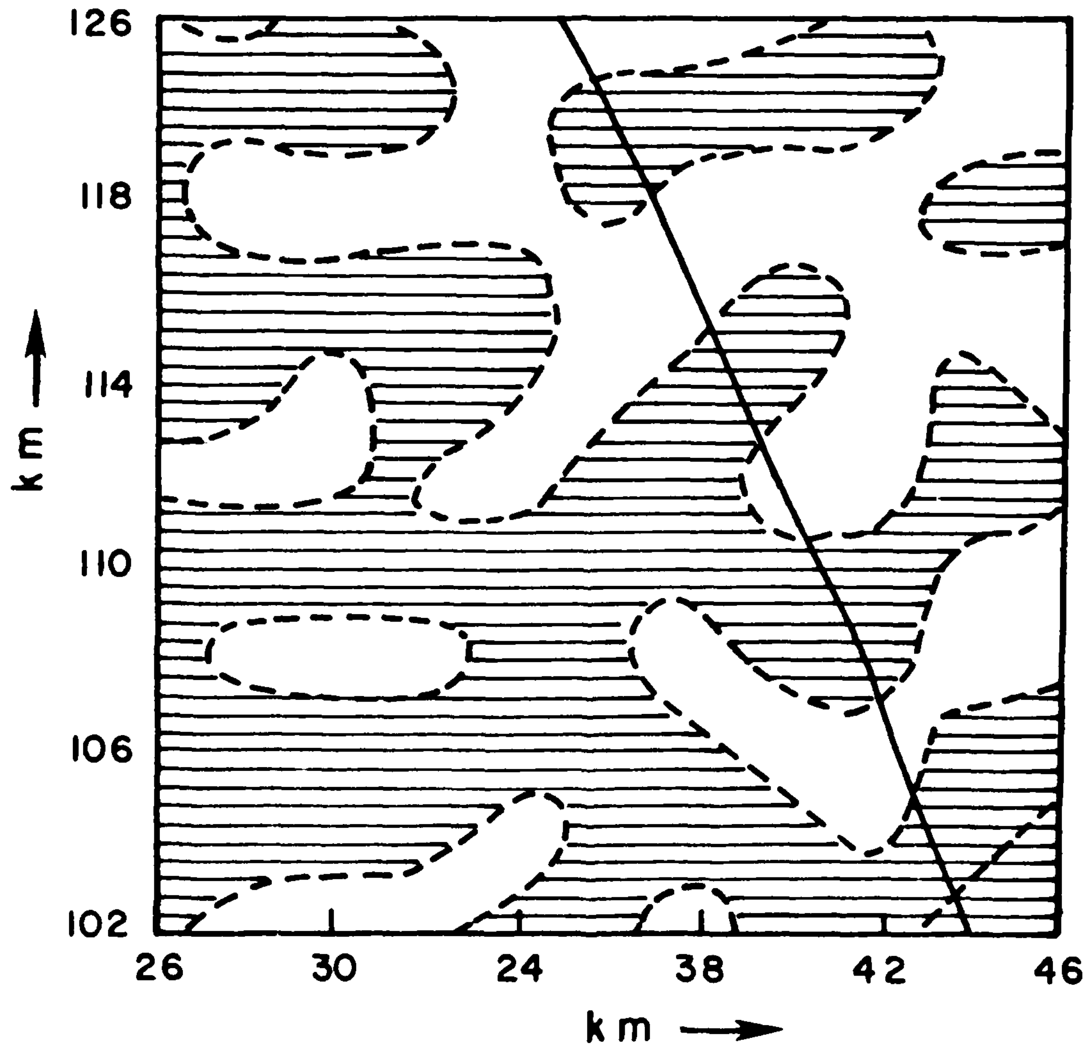
A STOCHASTIC SNAPSHOT WITH FRACTALS

BASIC WAVELENGTH: 340 km

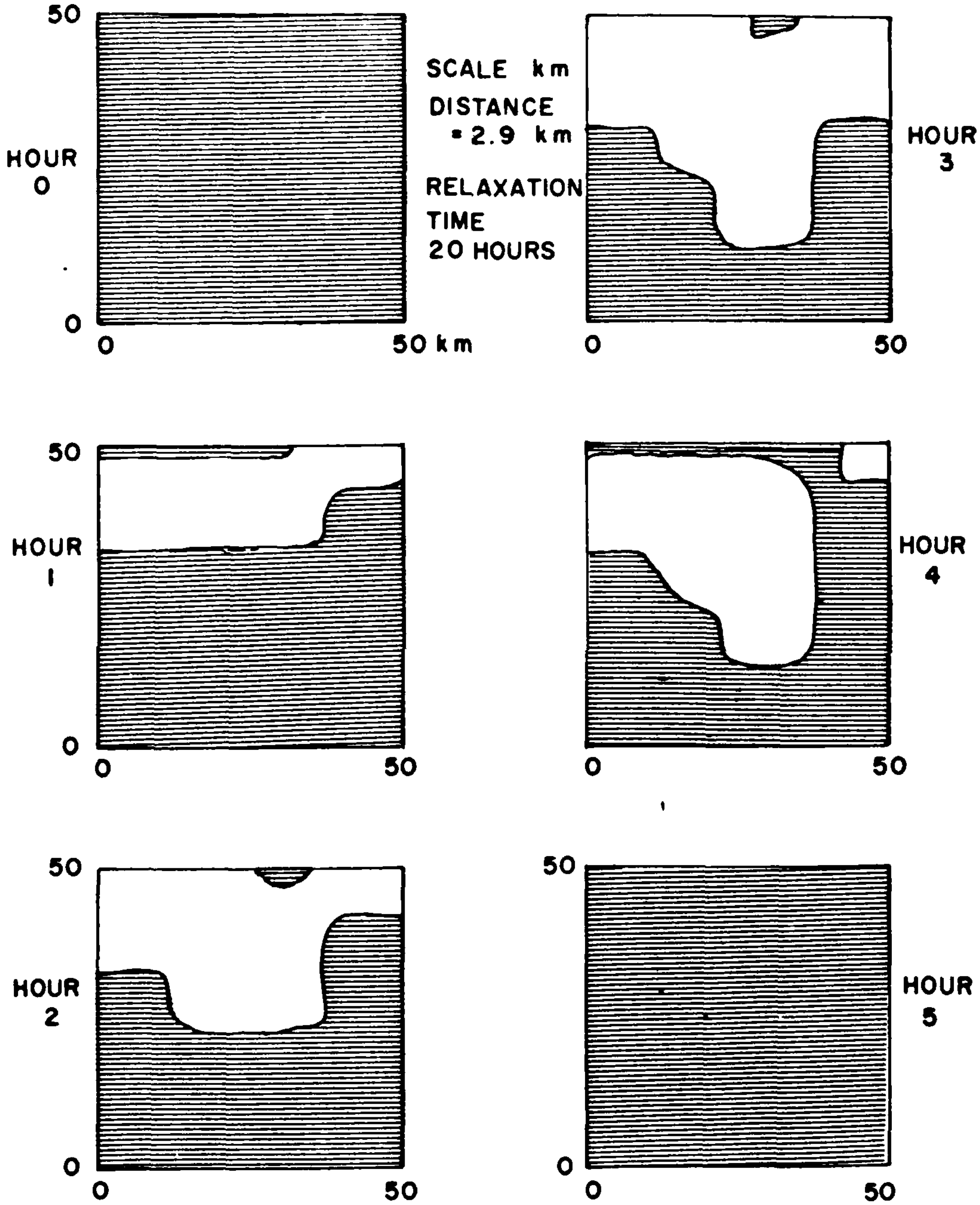
SMALLER WAVELENGTH: 5 km

CORRELATION: 0.95

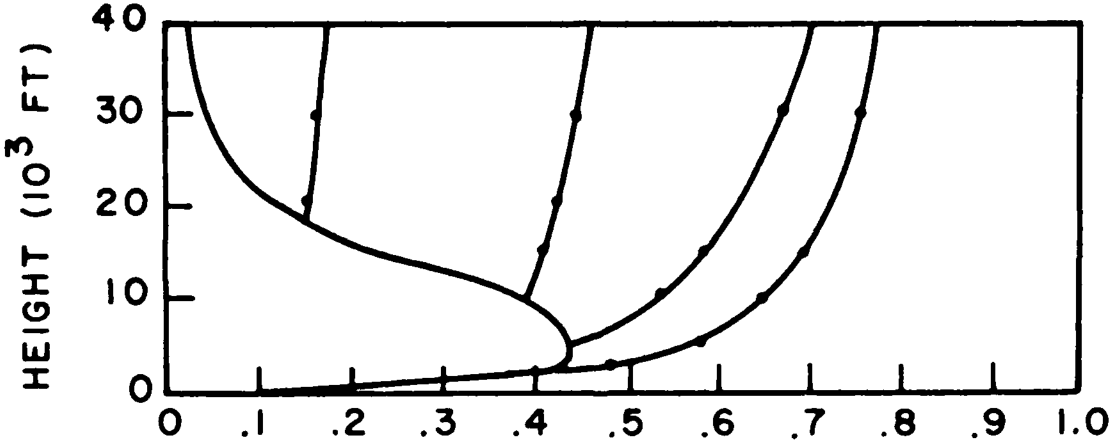
AREA: $(20\ km)^2$



SAMPLE TIME CHANGES IN AREA: SKY-DOME SIZE



MEAN CLOUD COVERS

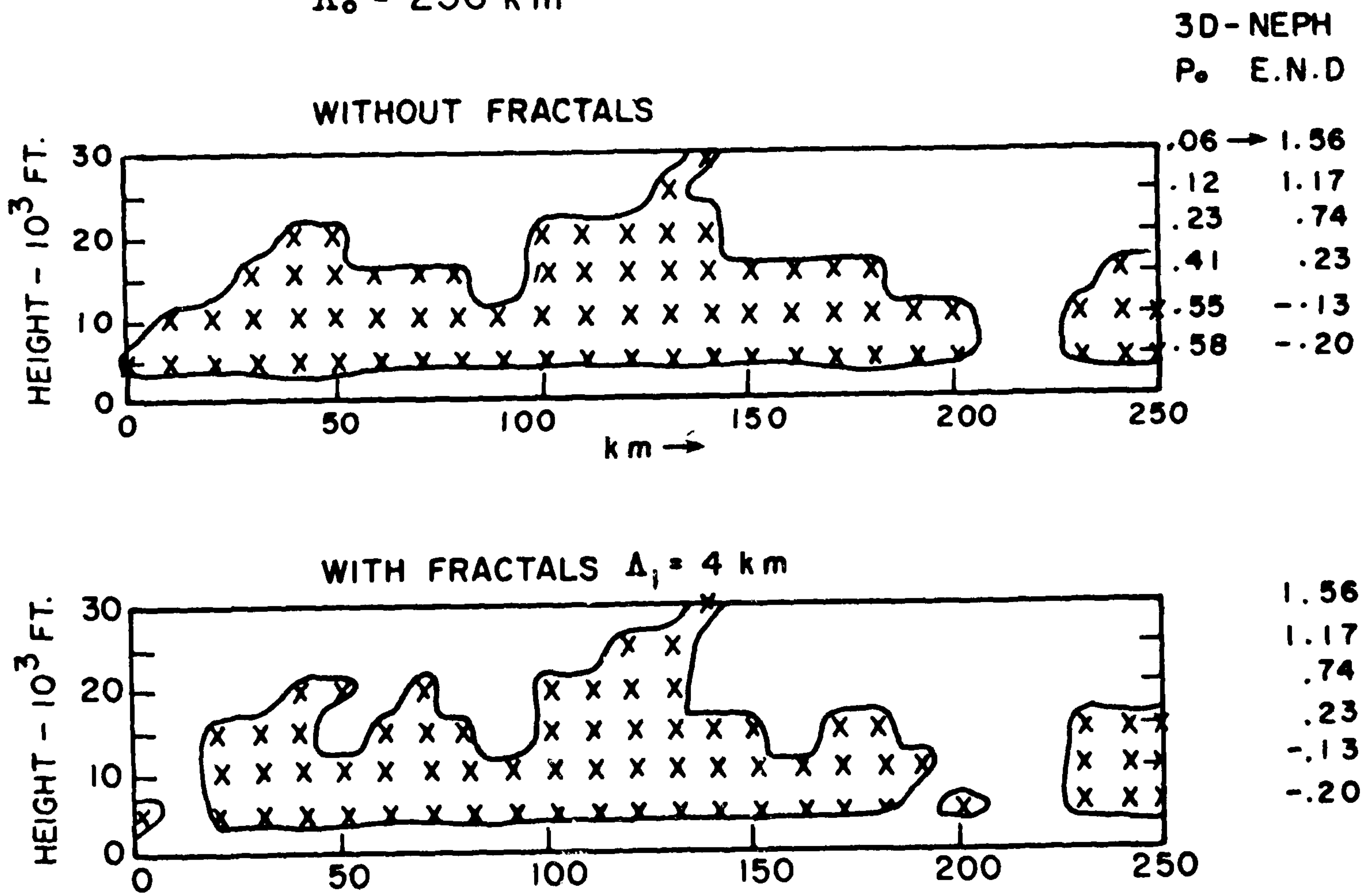


FROM 3D - NEPHANALYSIS
FOR CENTROL EUROPE; SOUTHERN MTs.
JANUARY, 0000Z

VERTICAL CLOUD SIMULATION

RANDON SEED :-579208732

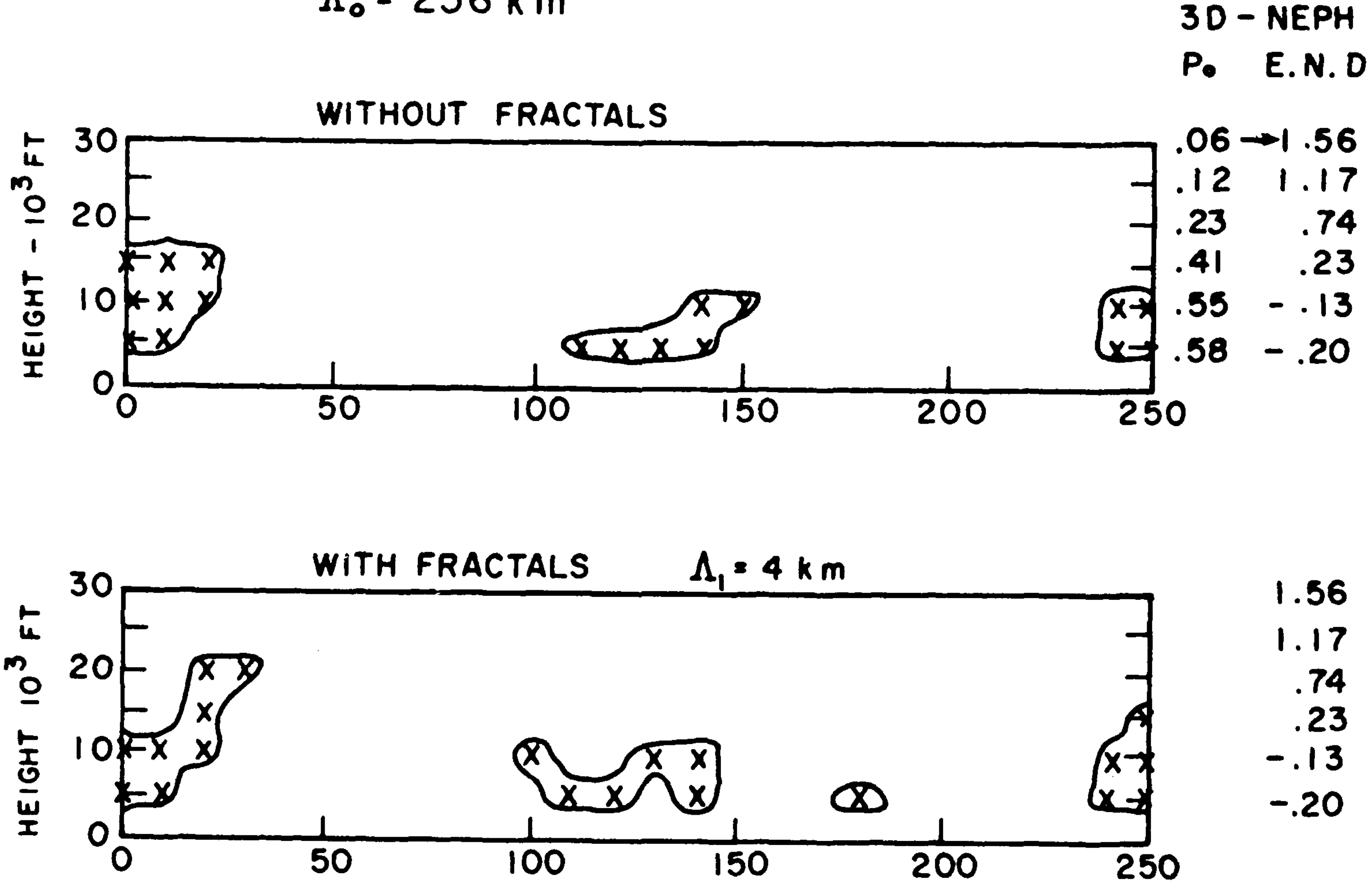
Λ_o = 256 km



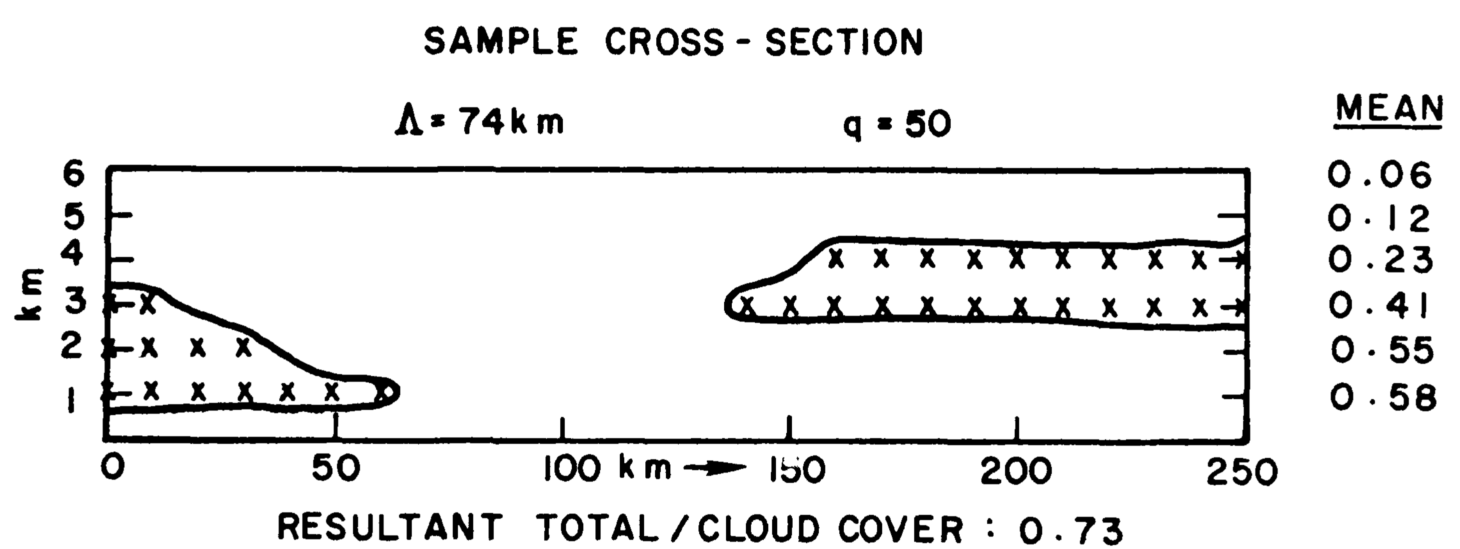
VERTICAL CLOUD SIMULATION

RANDOM SEED :-555125210

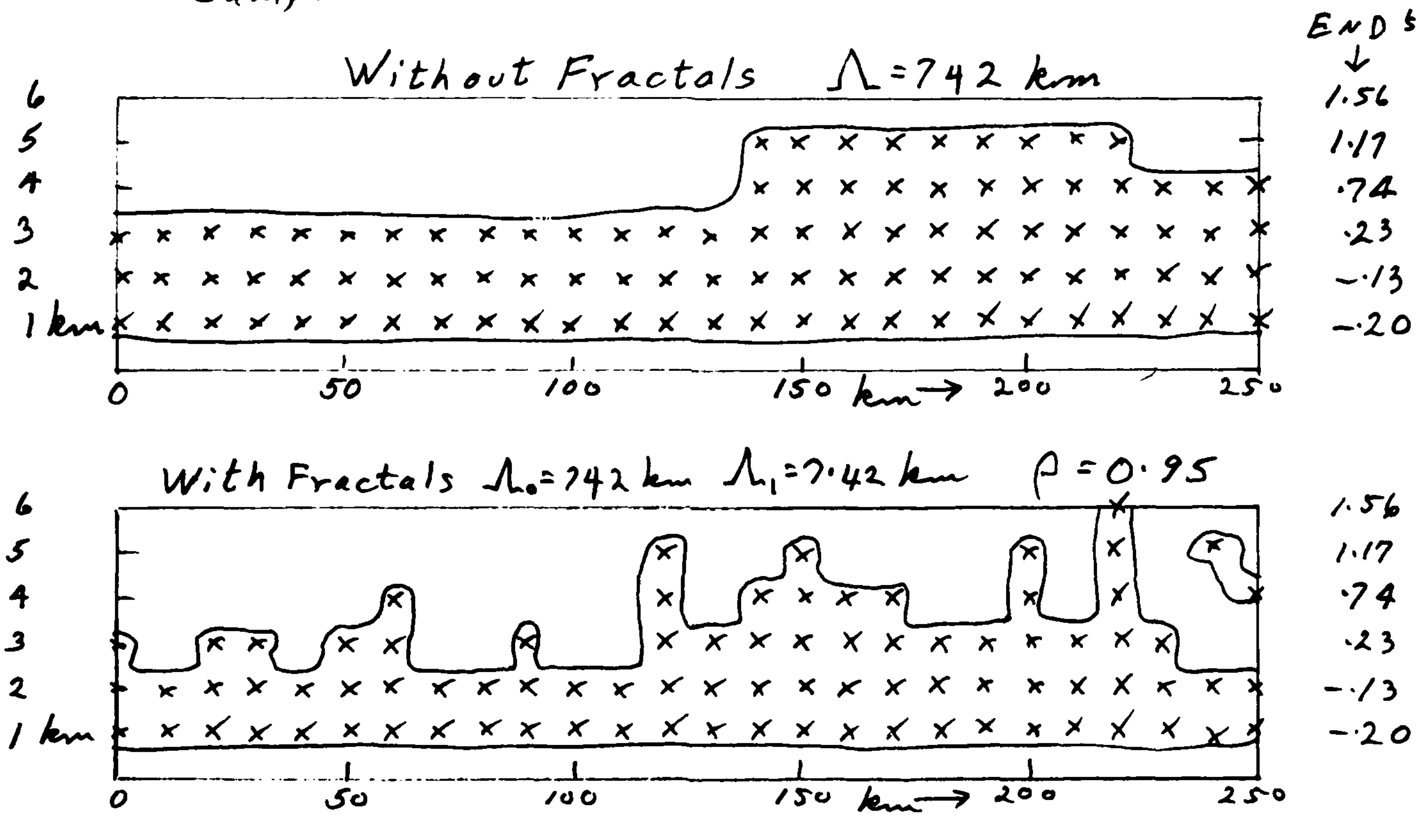
$\Lambda_o = 256$ km



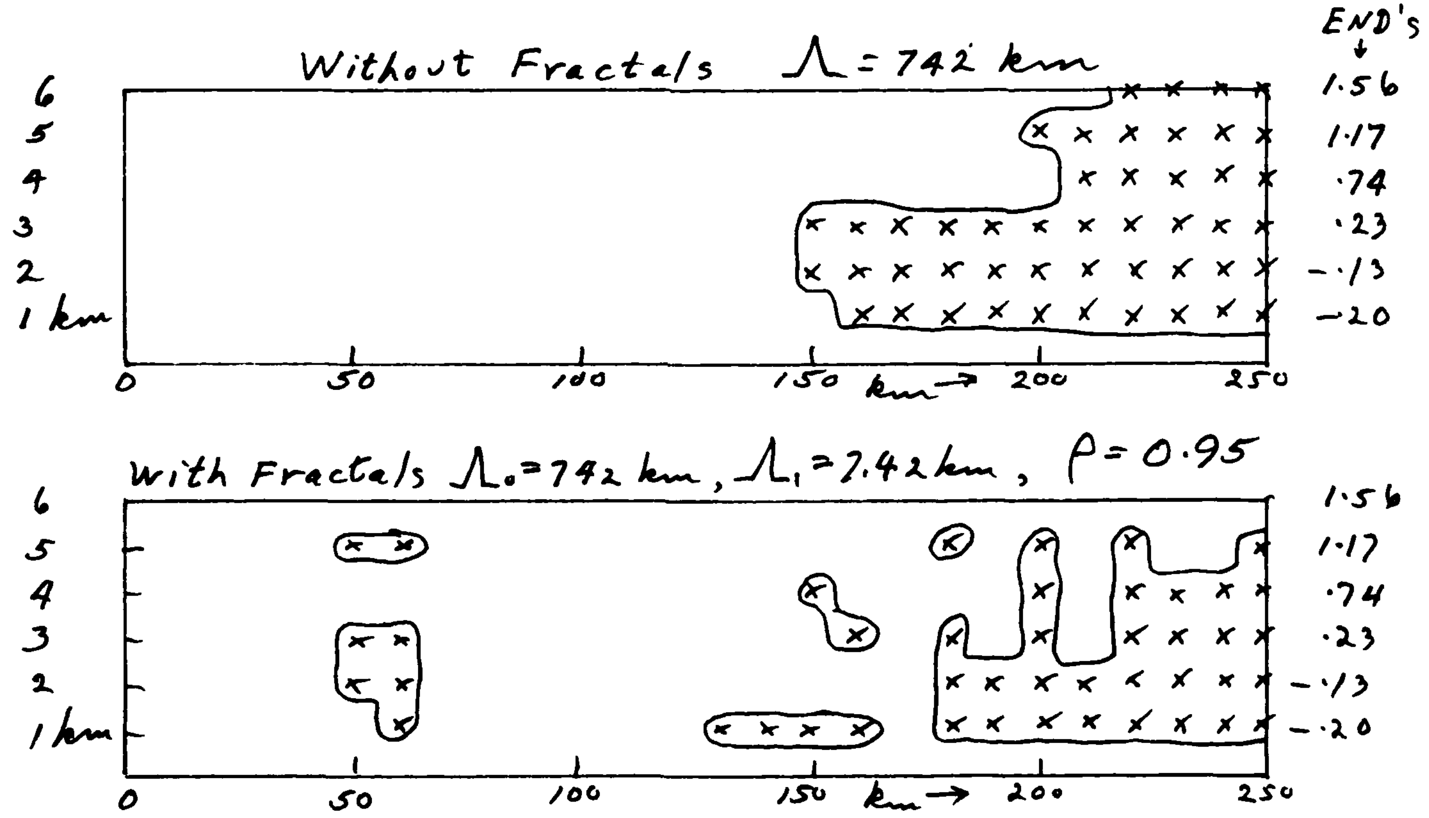
-JUN 20


SAMPLE CROSS-SECTION
Λ = 74 km
q = 50
MEAN
0.06
0.12
0.23
0.41
0.55
0.58
km
6
5
4
3
2
1
0
50
100 km → 150
200
250
RESULTANT TOTAL / CLOUD COVER : 0.73

Sample Vertical Cross-section



Sample Vertical Cross section



CORRELATION FUNCTIONS FOR CLOUD COVER AND CEILING

Ralph Shapiro
Systems and Applied Sciences Corporation

CORRELATION FUNCTIONS FOR CLOUD COVER AND CEILING

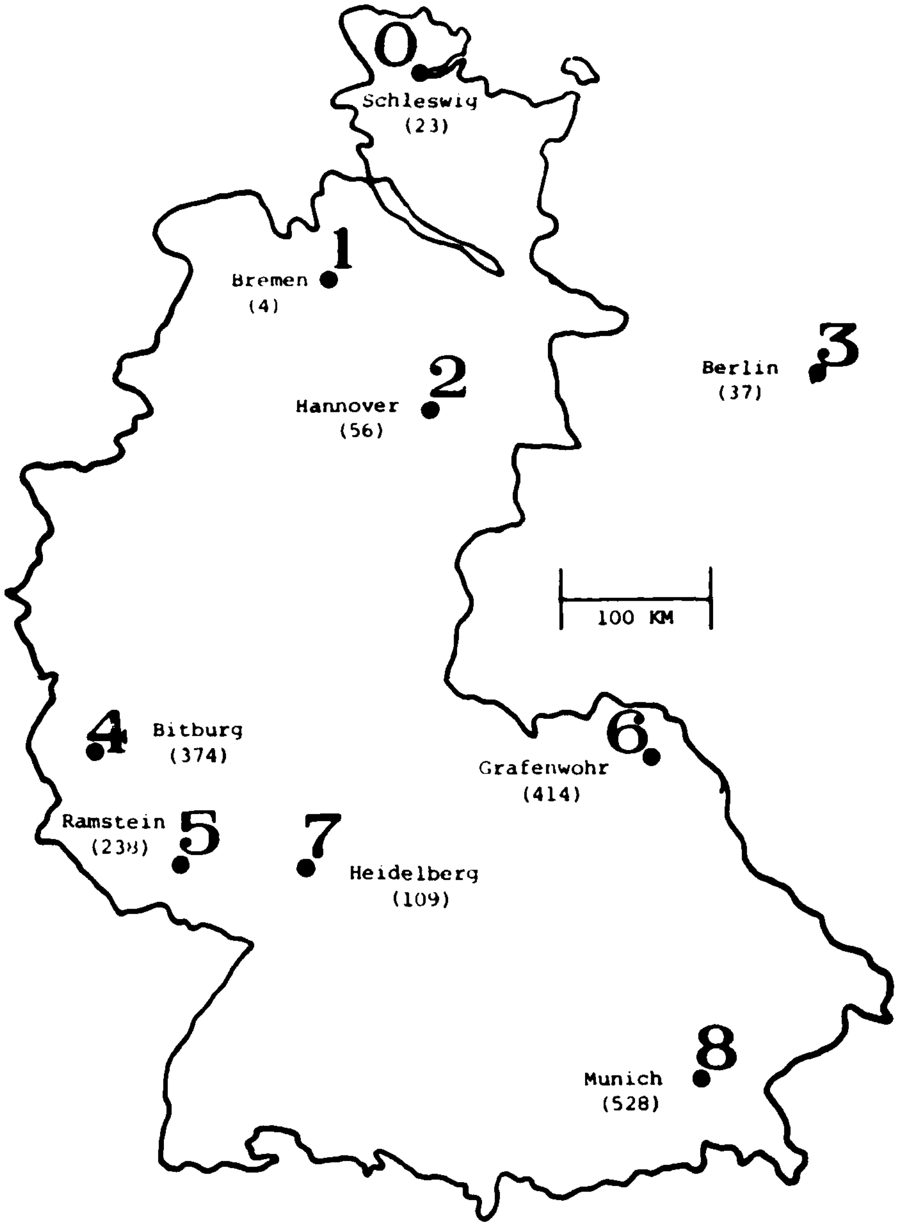
Ralph Shapiro
Systems and Applied Sciences Corporation

ABSTRACT

Short-term (0-12 hour) prediction of the weather at a point depends primarily on the immediate past meteorological history at the point. This dependence is sufficiently pronounced to permit the development of a highly successful short-term, point forecast methodology that makes exclusive use of the current values of the meteorological parameters at the point in question. This procedure, known by the acronym GEM (Generalized Exponential Markov), was devised for operational use by Bob Miller at the Techniques Development Laboratory of the National Weather Service. Unfortunately, for many military applications, forecasts or specifications are required for locations without observing stations, or where the observations are otherwise unavailable. GEM is not useful for such applications, and it is necessary to infer the weather at the point in question by other means.

Objective analysis procedures, especially in data-sparse regions, make use of the fact that weather is coherent in space as well as time. Knowledge of the weather at one point implies some knowledge of the weather at nearby locations. The rate at which the information at one point decays with distance is a function of the typical scale size of the parameter involved and is efficiently summarized by means of spatial correlation functions. Such functions have been obtained for a variety of meteorological parameters for several widely separated geographical regions--Germany, Korea, the Middle East, and Central America. Correlation functions for ceiling and cloud cover will be illustrated for these regions and will be compared with correlation functions for other parameters such as pressure and temperature, possessing greater coherence.

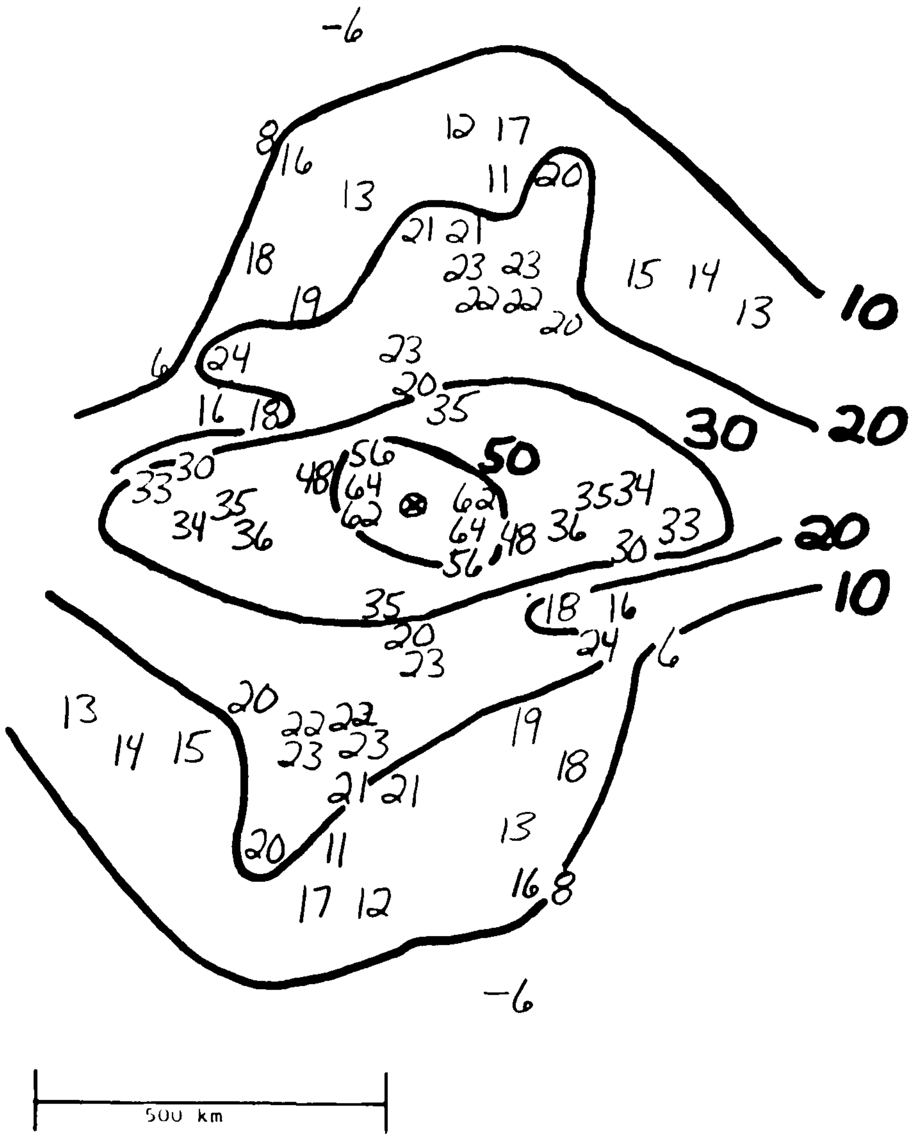
Correlation functions are obtained with hourly data, except where indicated as three-hourly data.



STATIONS IN GERMANY. ELEVATION IN METERS IN PARENTHESES.

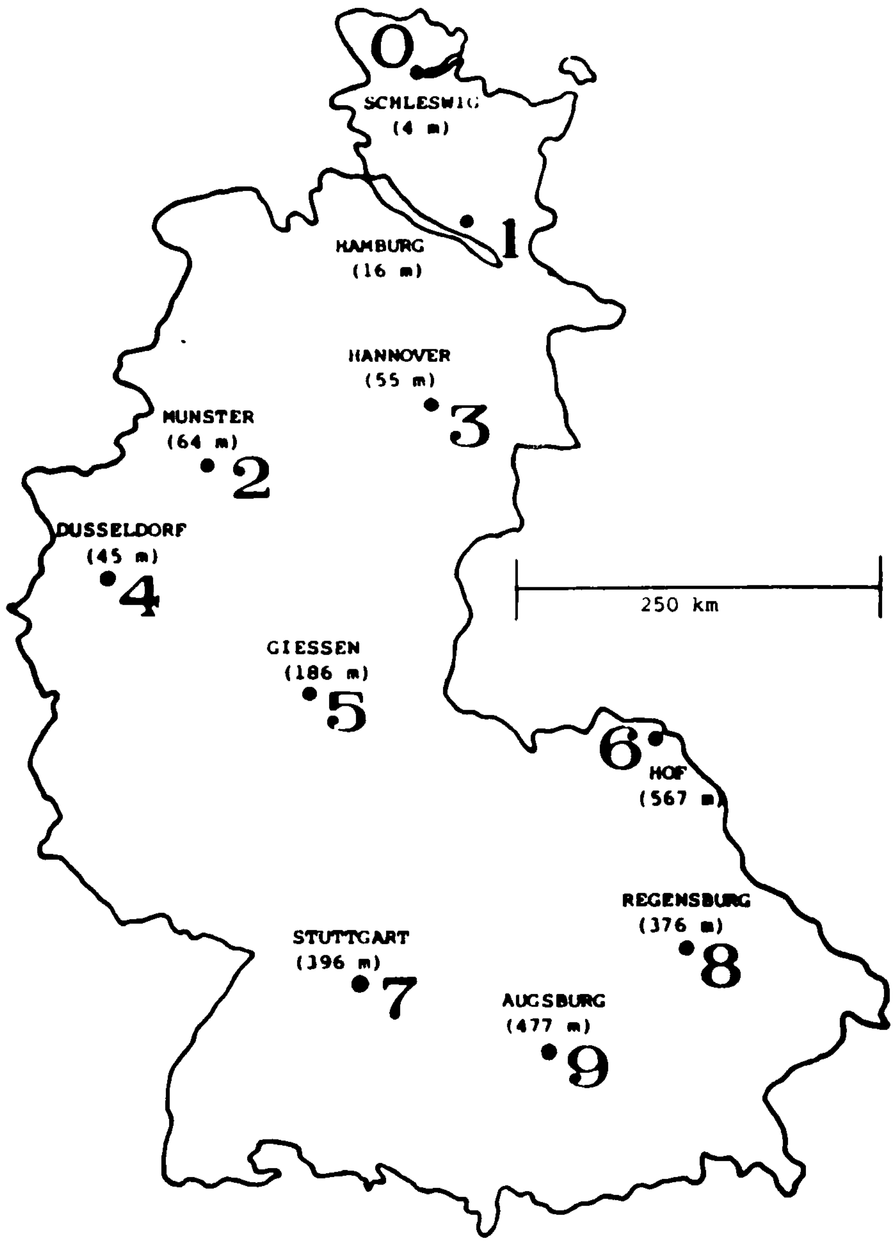
GERMANY. STATION PAIRS

SPATIAL AUTOCORRELATION
GERMANY - WINTER
CEILING CATEGORY

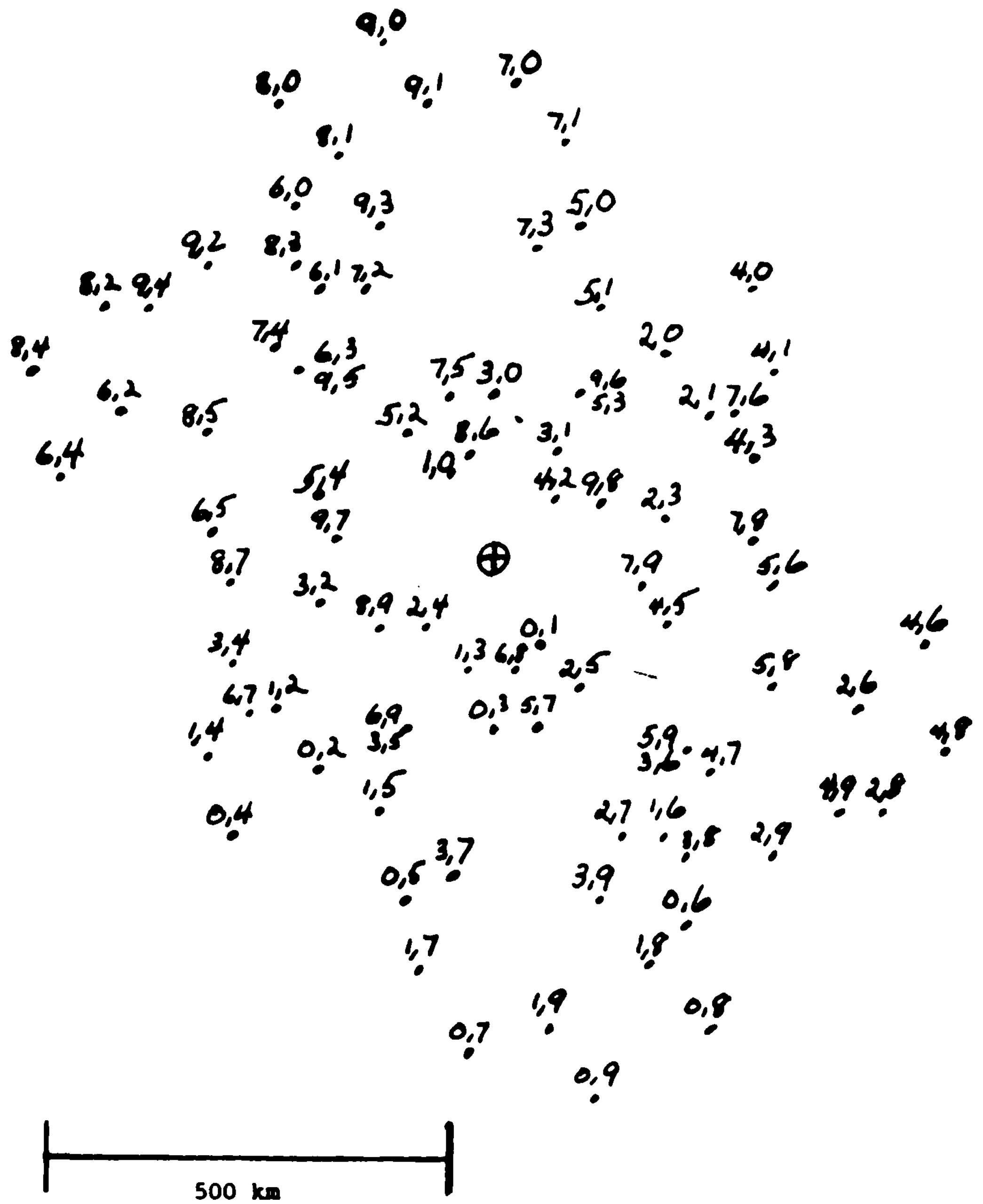


CEILING CATEGORY

1	> 10,000 FT
2	5,001 - 10,000
3	3,001 - 5,000
4	2,001 - 3,000
5	1,001 - 2,000
6	501 - 1,000
7	201 - 500
8	0 - 200

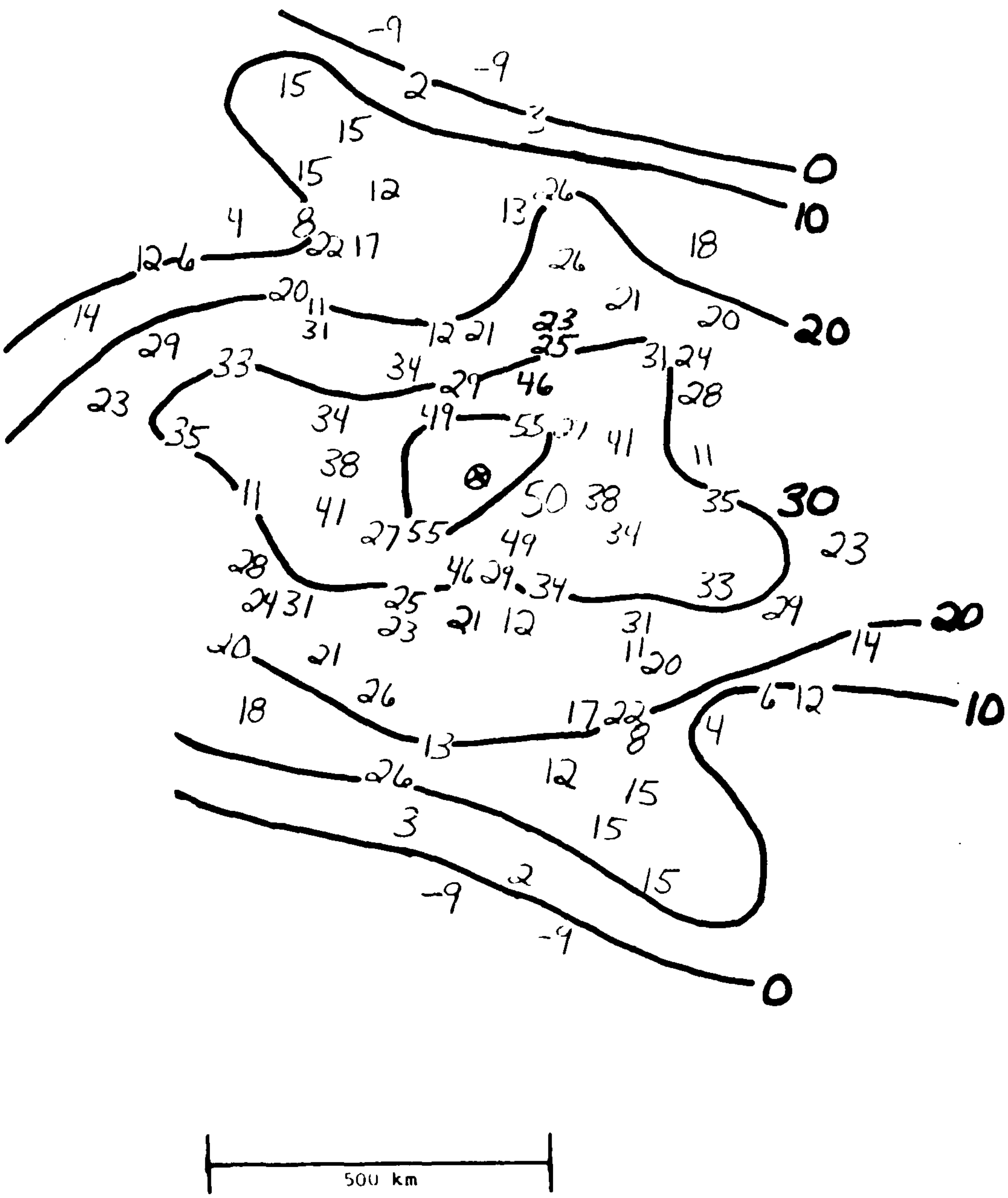


GERMAN STATIONS, 3-HOURLY DATA



GERMANY. STATION PAIRS (3-HOURLY DATA)

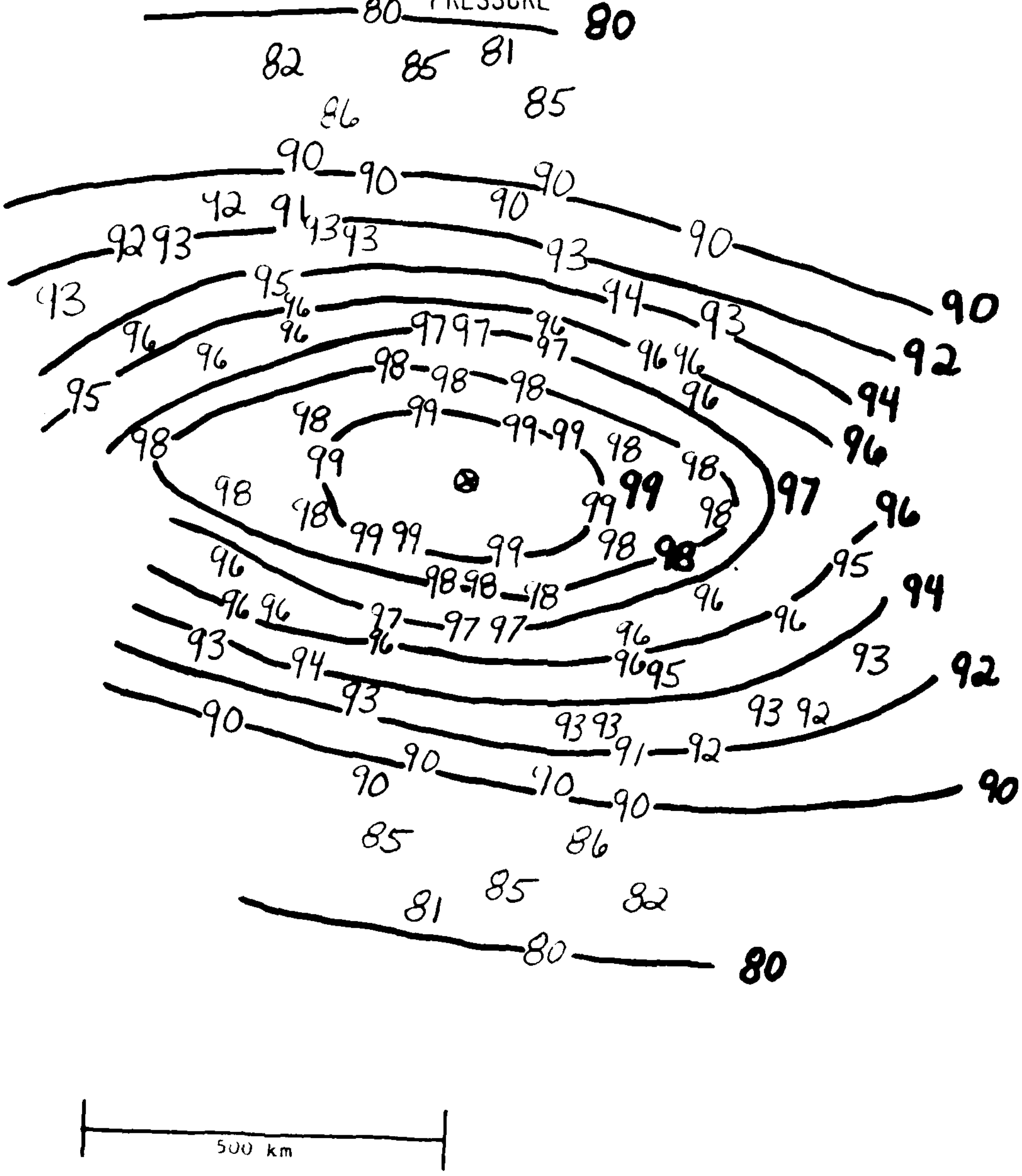
SPATIAL AUTOCORRELATION
GERMANY - WINTER
CEILING CATEGORY (3-HOURLY DATA)



SPATIAL AUTOCORRELATION

GERMANY - WINTER

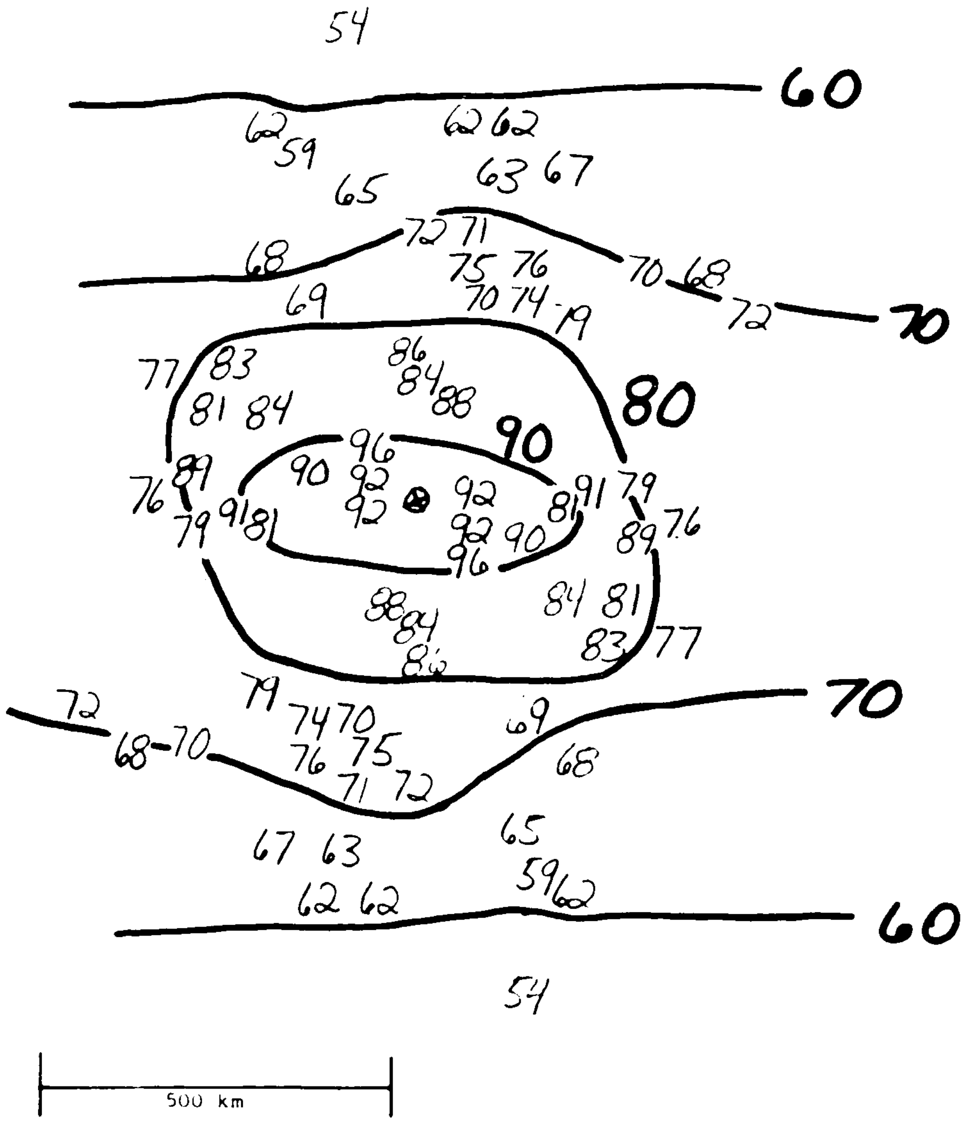
PRESSURE (3-HOURLY DATA)



SPATIAL AUTOCORRELATION

GERMANY - WINTER

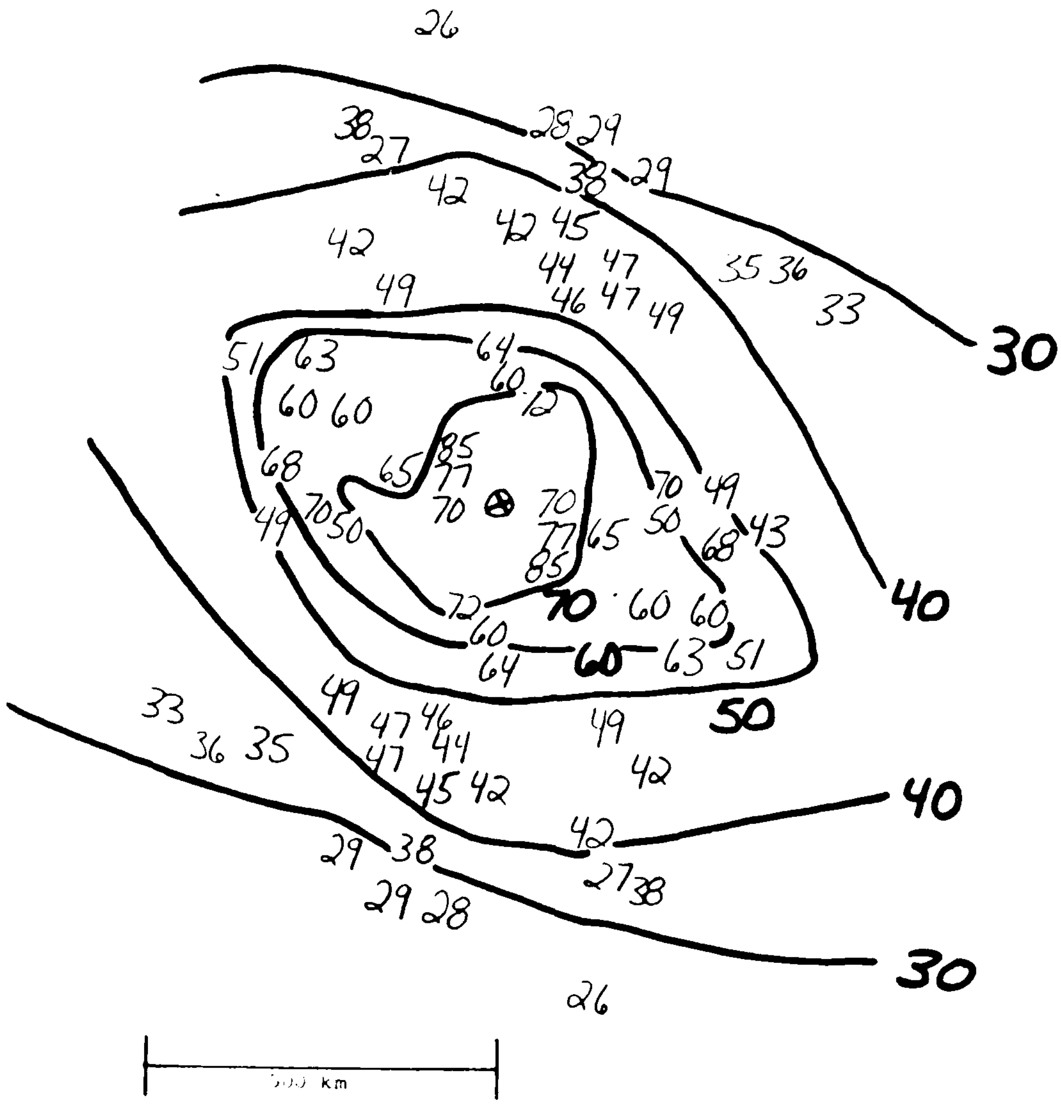
TEMPERATURE



SPATIAL AUTOCORRELATION

GERMANY - WINTER

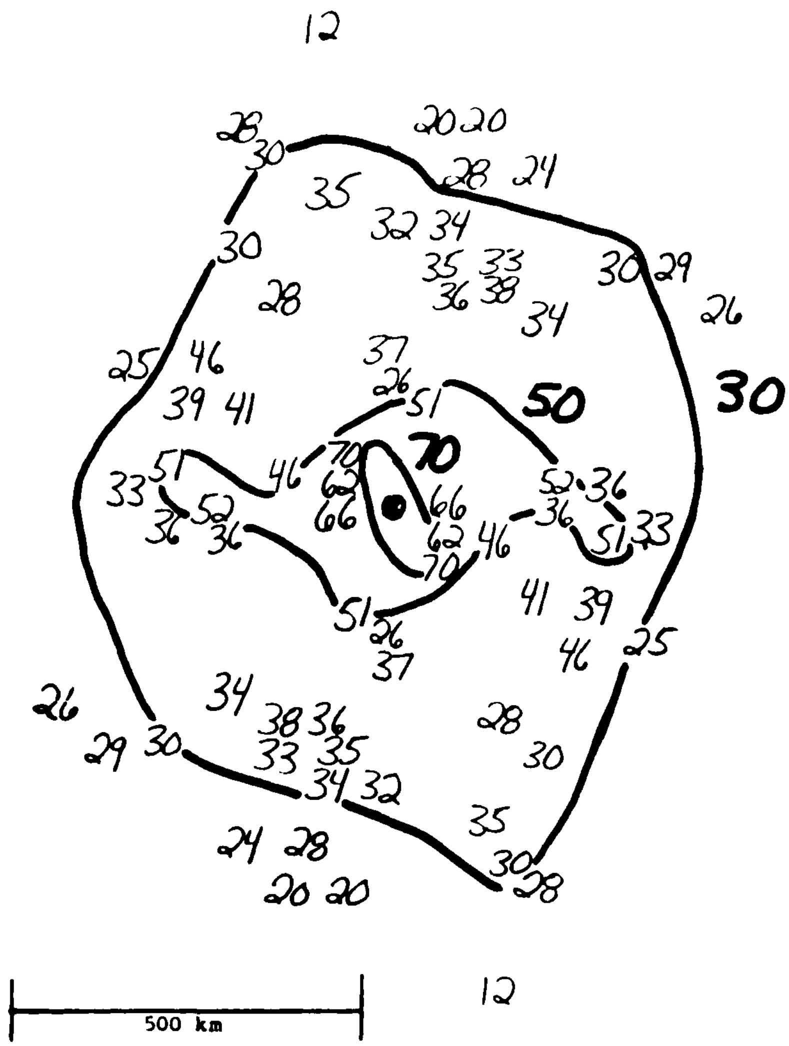
WIND SPEED



SPATIAL AUTOCORRELATION

GERMANY - WINTER

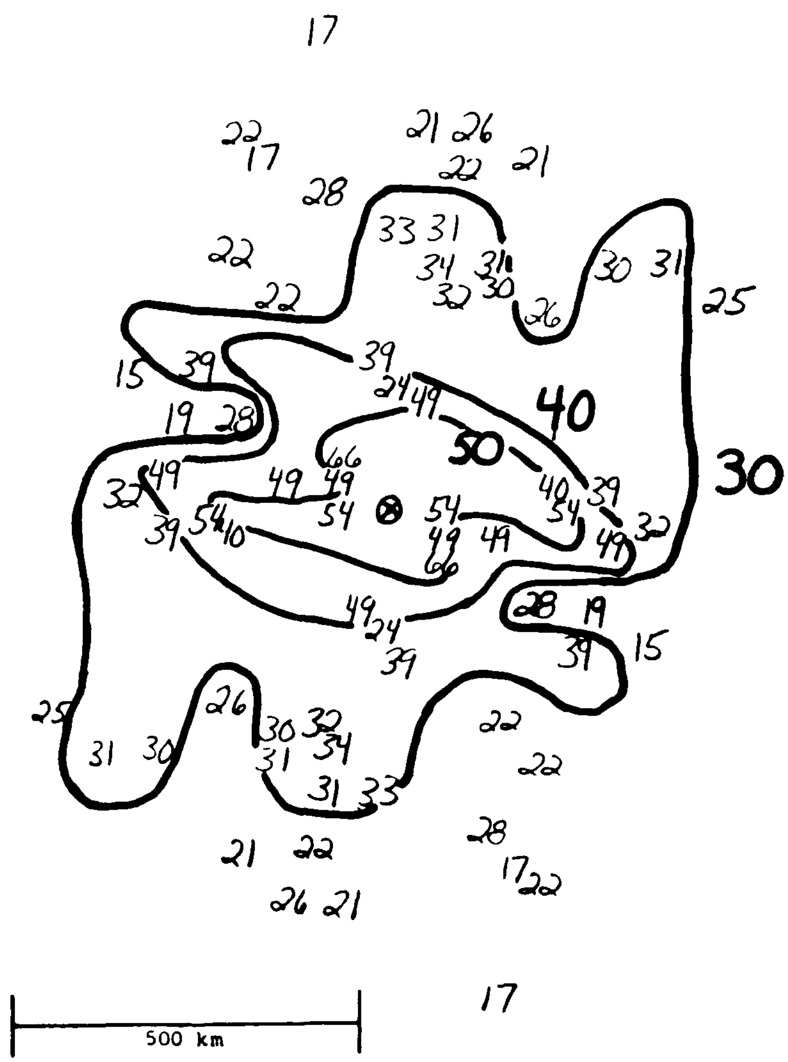
VISIBILITY



SPATIAL AUTOCORRELATION

GERMANY - WINTER

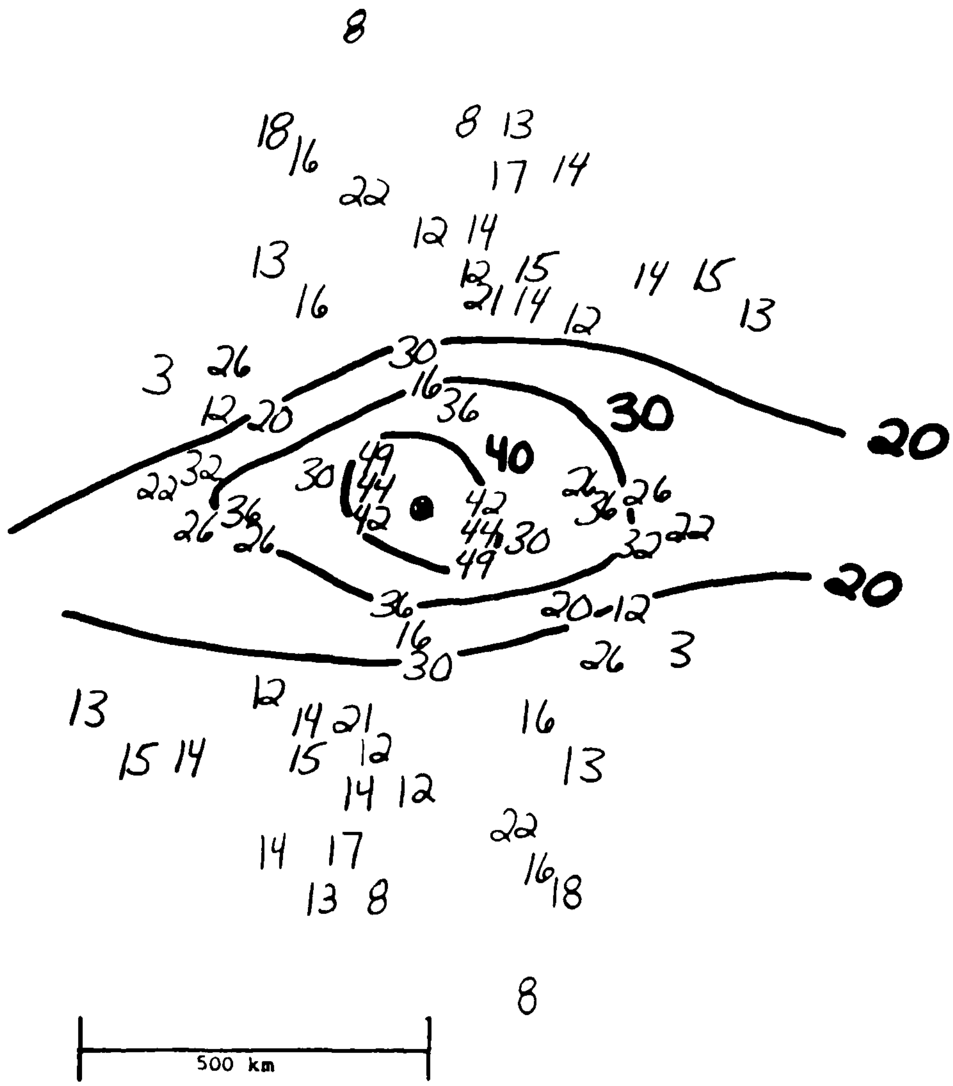
RELATIVE HUMIDITY



SPATIAL AUTOCORRELATION

GERMANY - WINTER

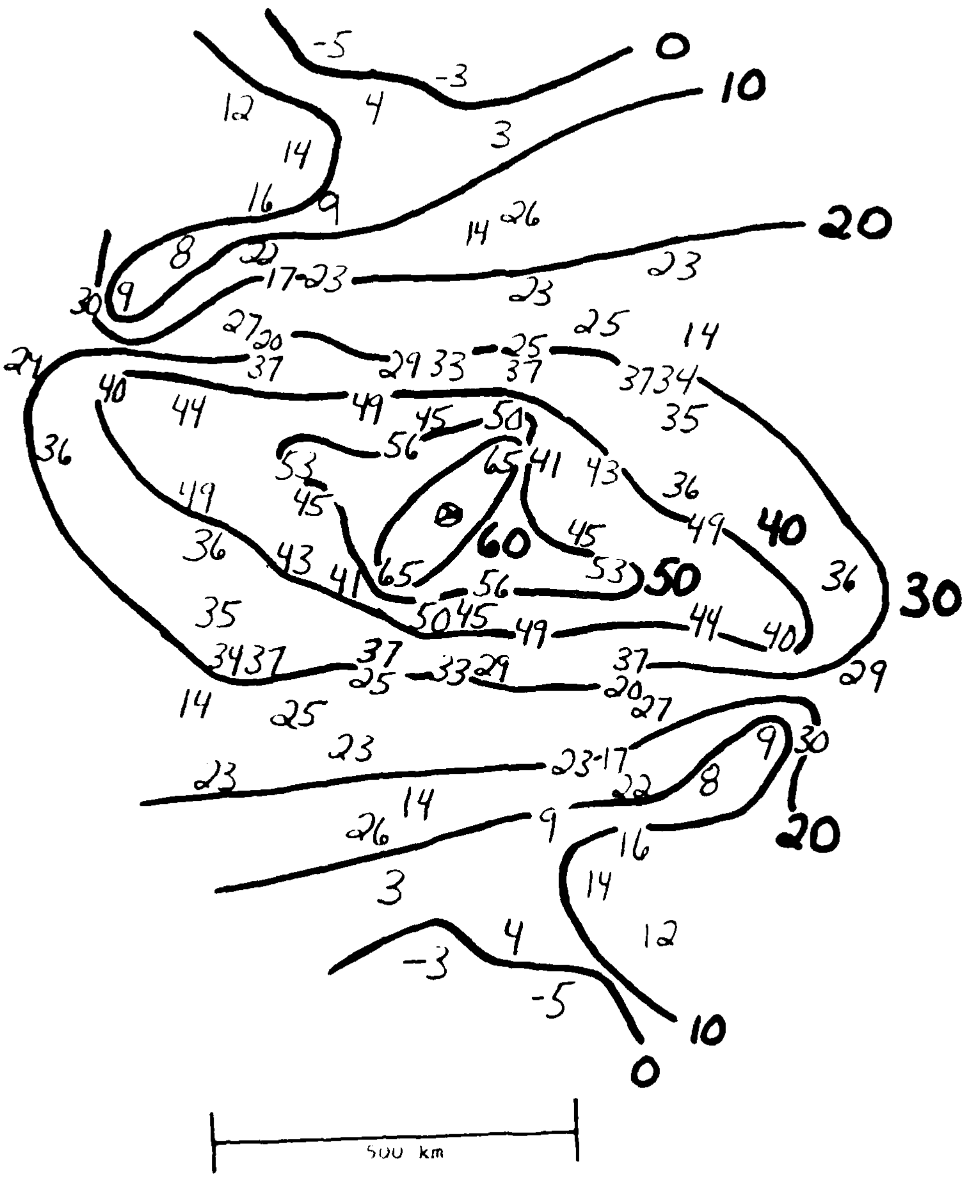
WEATHER CATEGORY



SPATIAL AUTOCORRELATION

GERMANY - WINTER

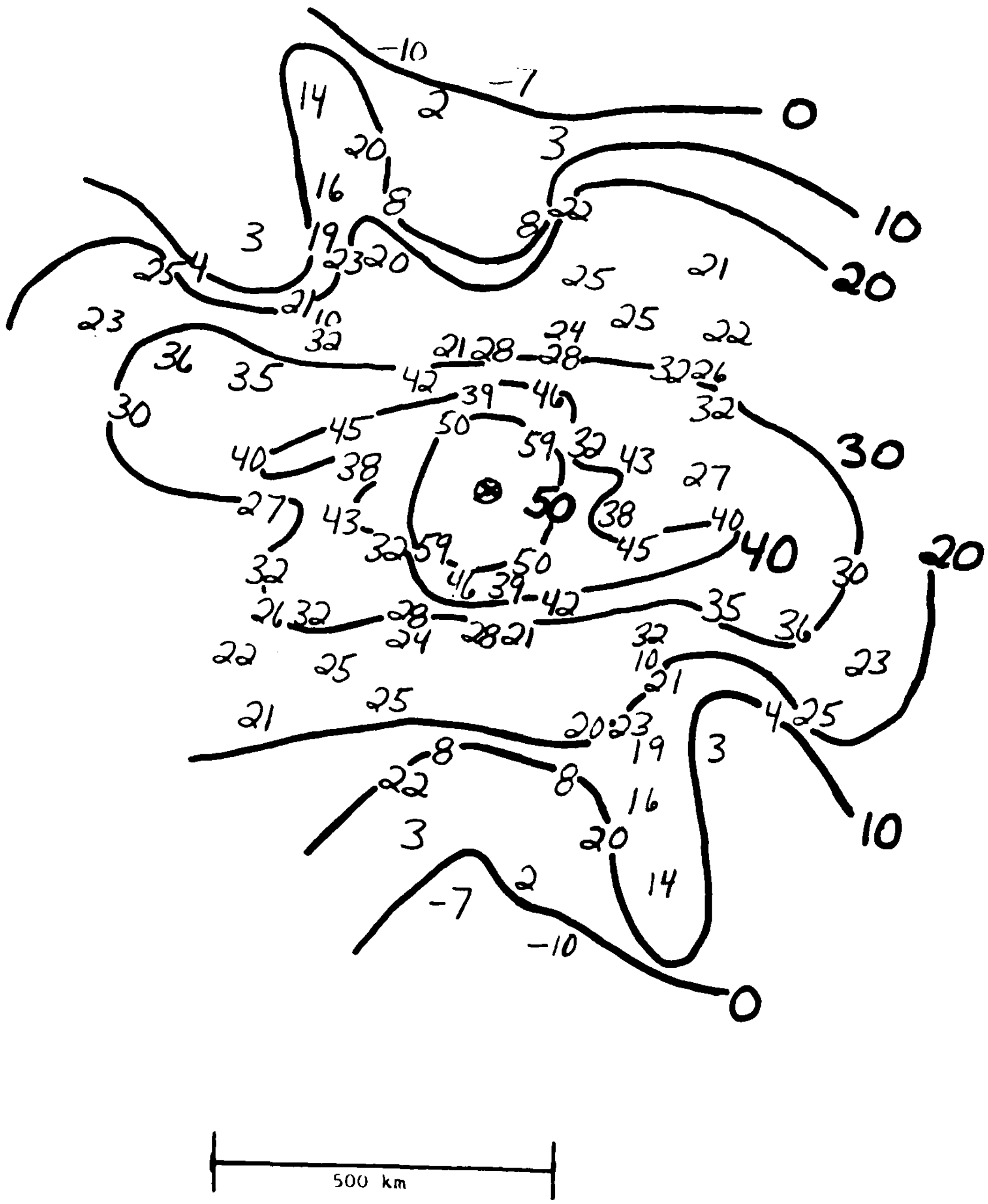
TOTAL CLOUD COVER



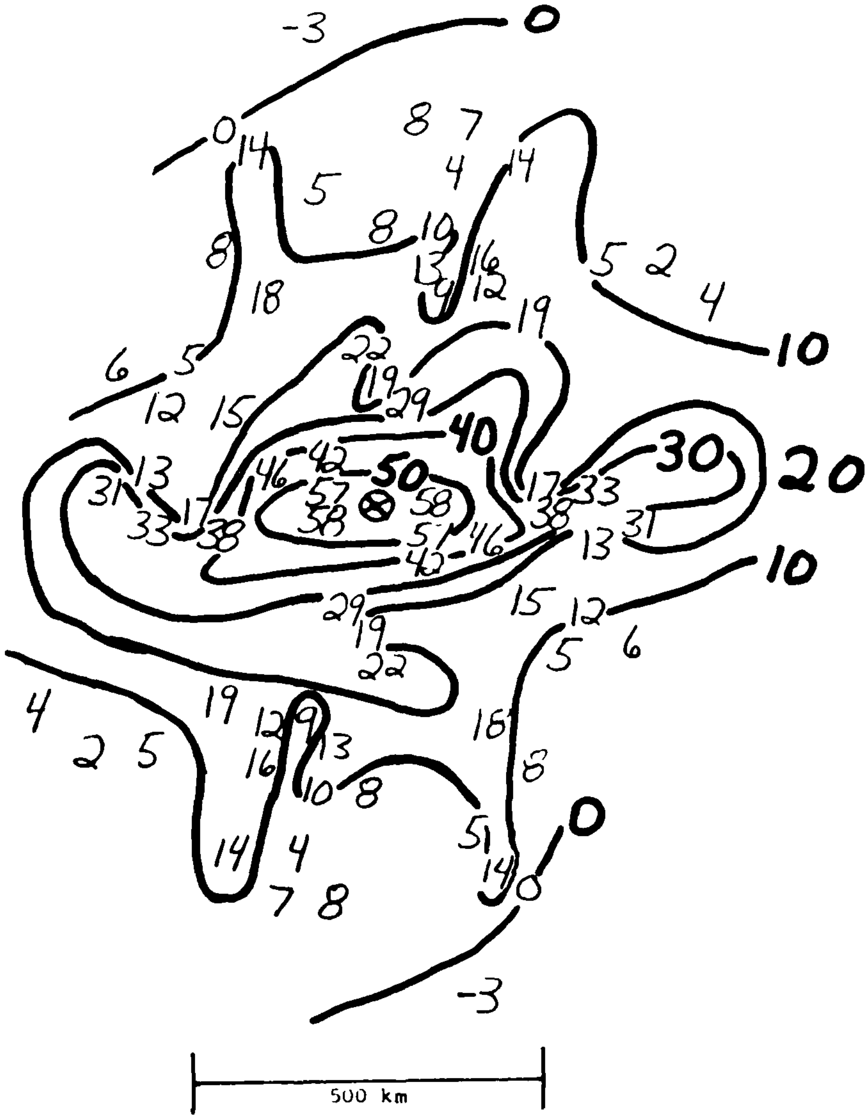
SPATIAL AUTOCORRELATION

GERMANY - WINTER

LOW CLOUD AMOUNT



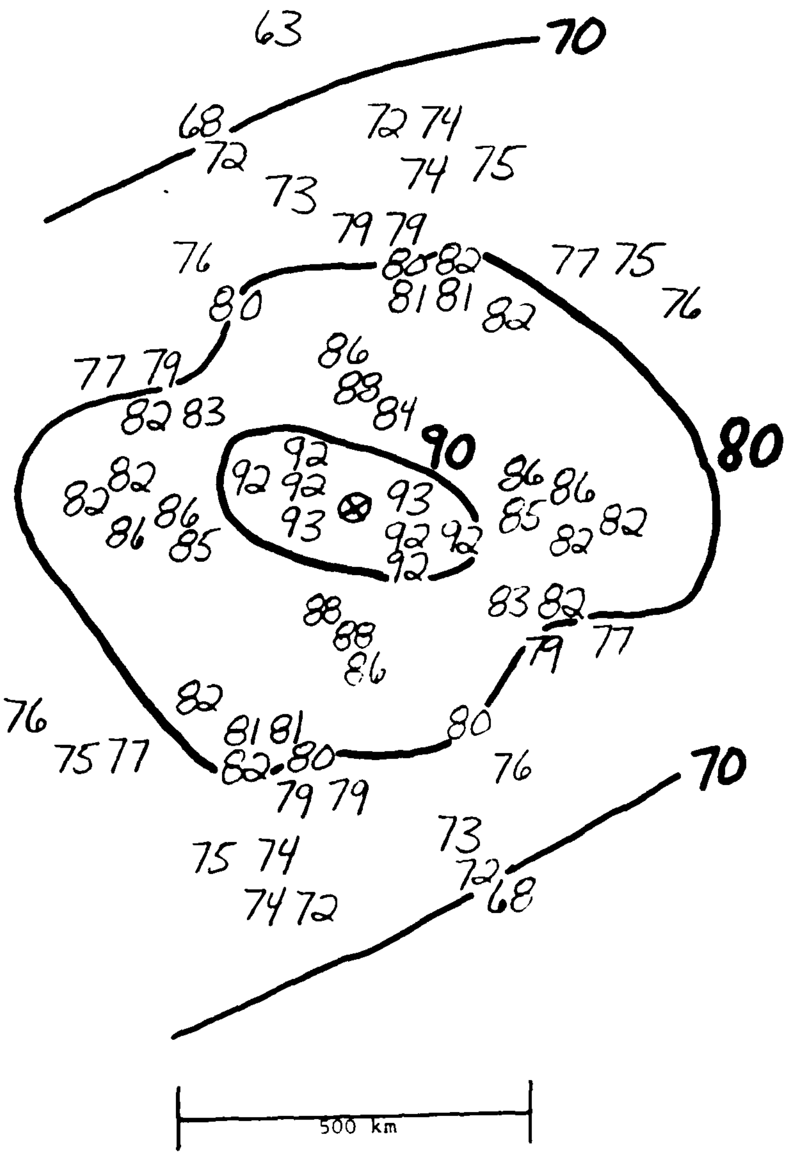
SPATIAL AUTOCORRELATION
GERMANY - SUMMER
CEILING CATEGORY



SPATIAL AUTOCORRELATION

GERMANY - SUMMER

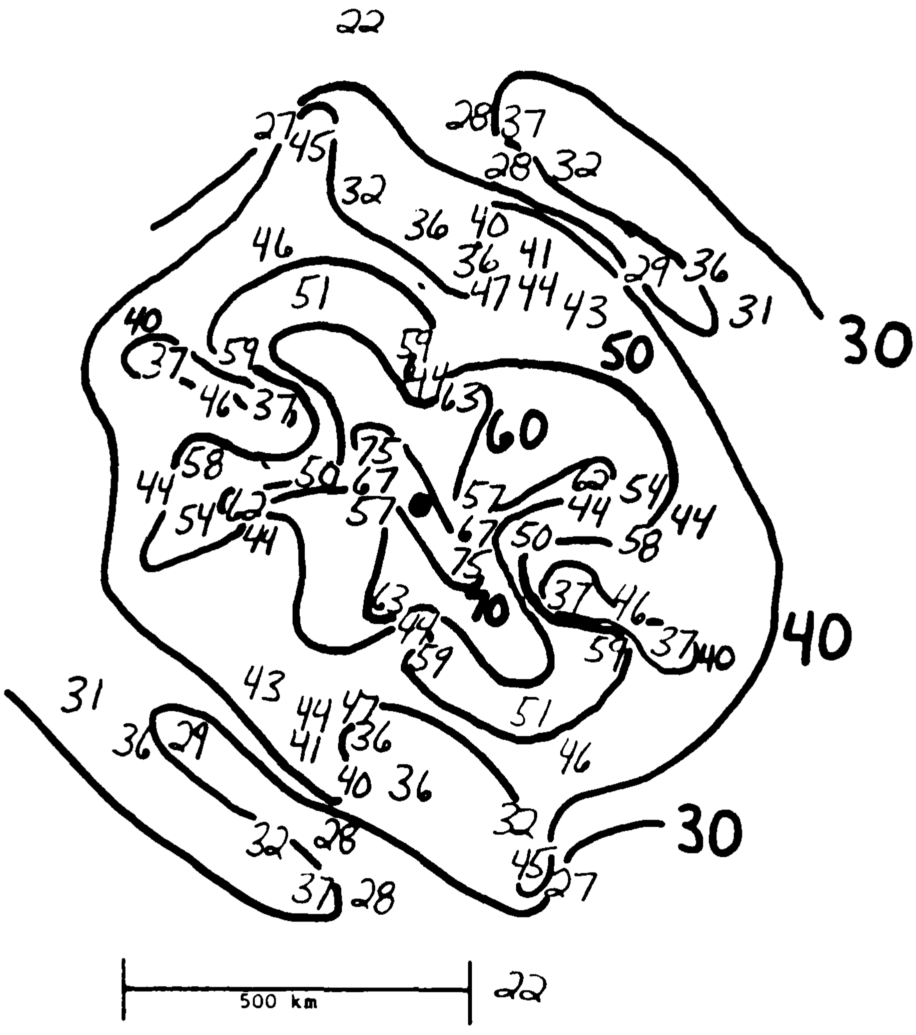
TEMPERATURE



SPATIAL AUTOCORRELATION

GERMANY - SUMMER

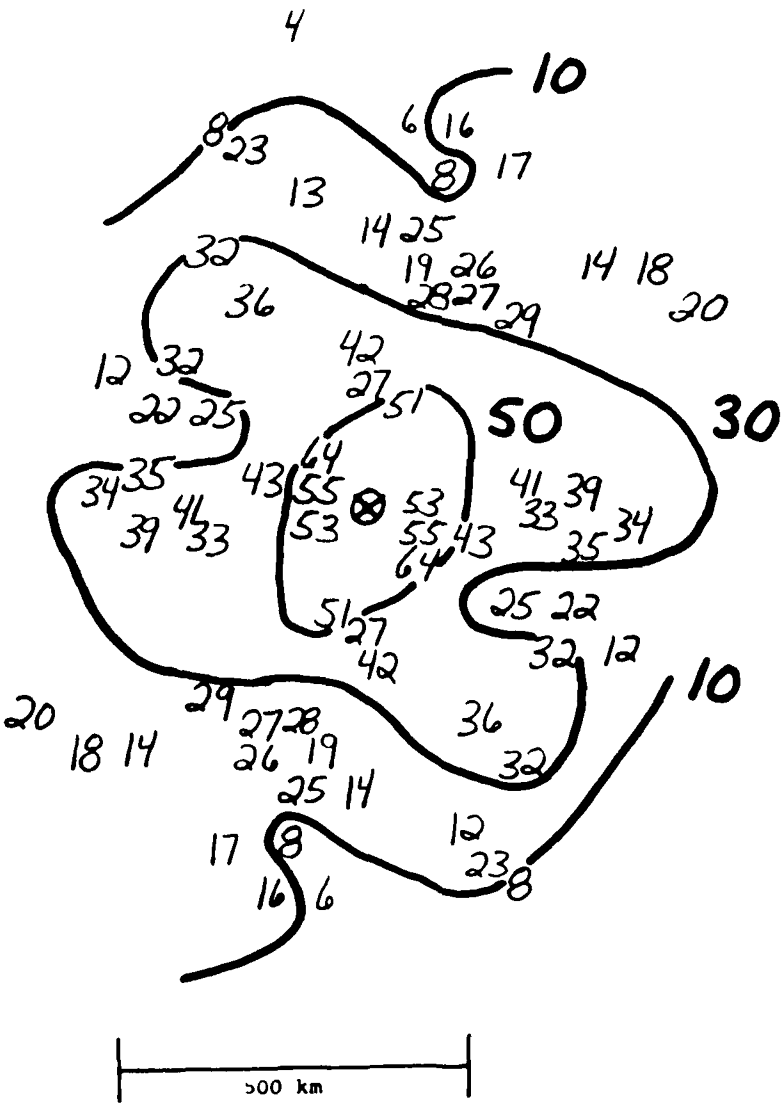
WIND SPEED



SPATIAL AUTOCORRELATION

GERMANY - SUMMER

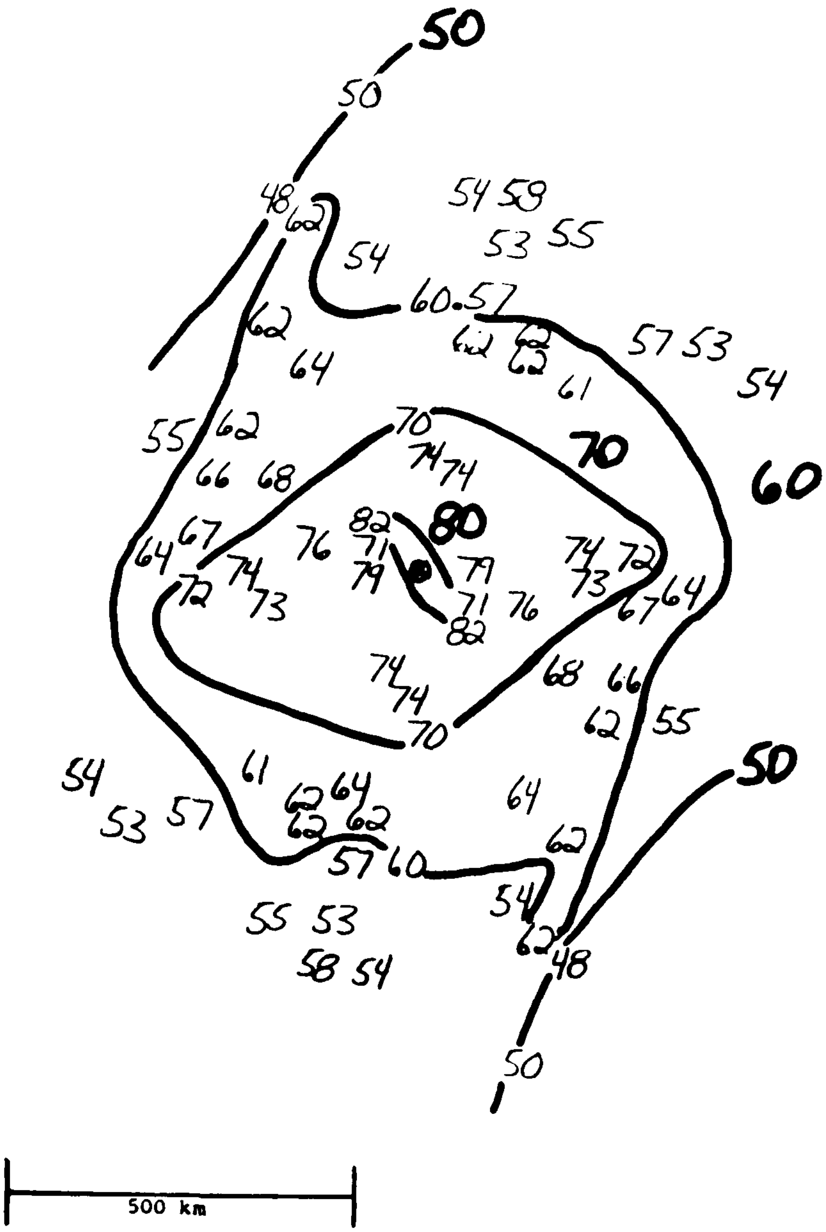
VISIBILITY



SPATIAL AUTOCORRELATION

GERMANY - SUMMER

RELATIVE HUMIDITY

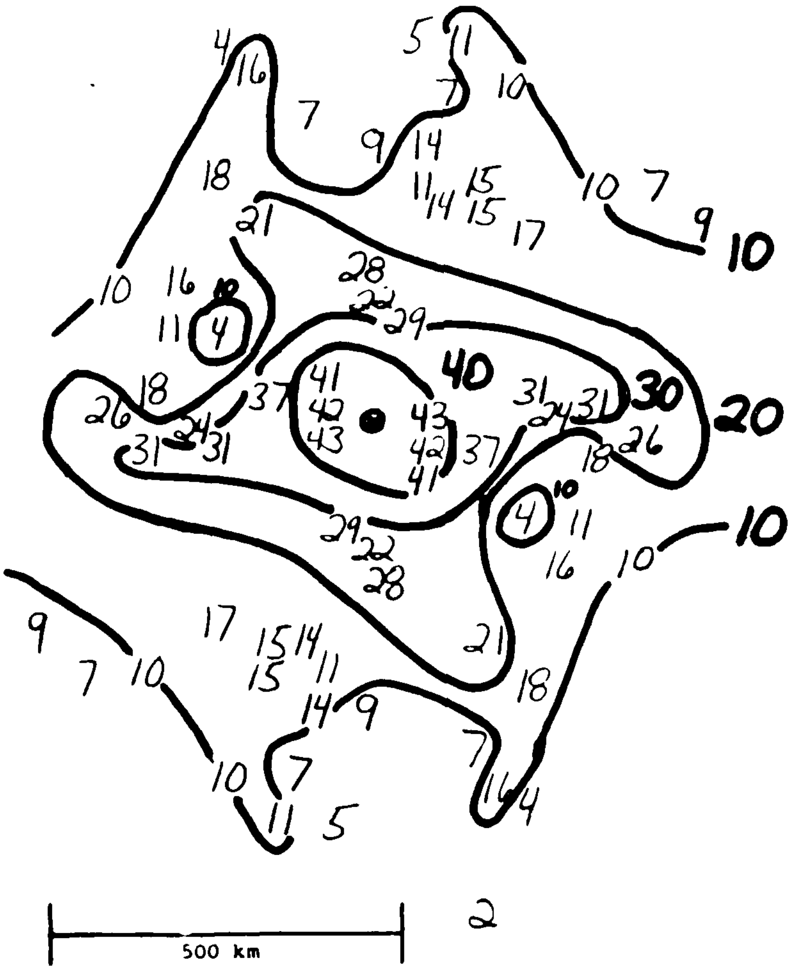


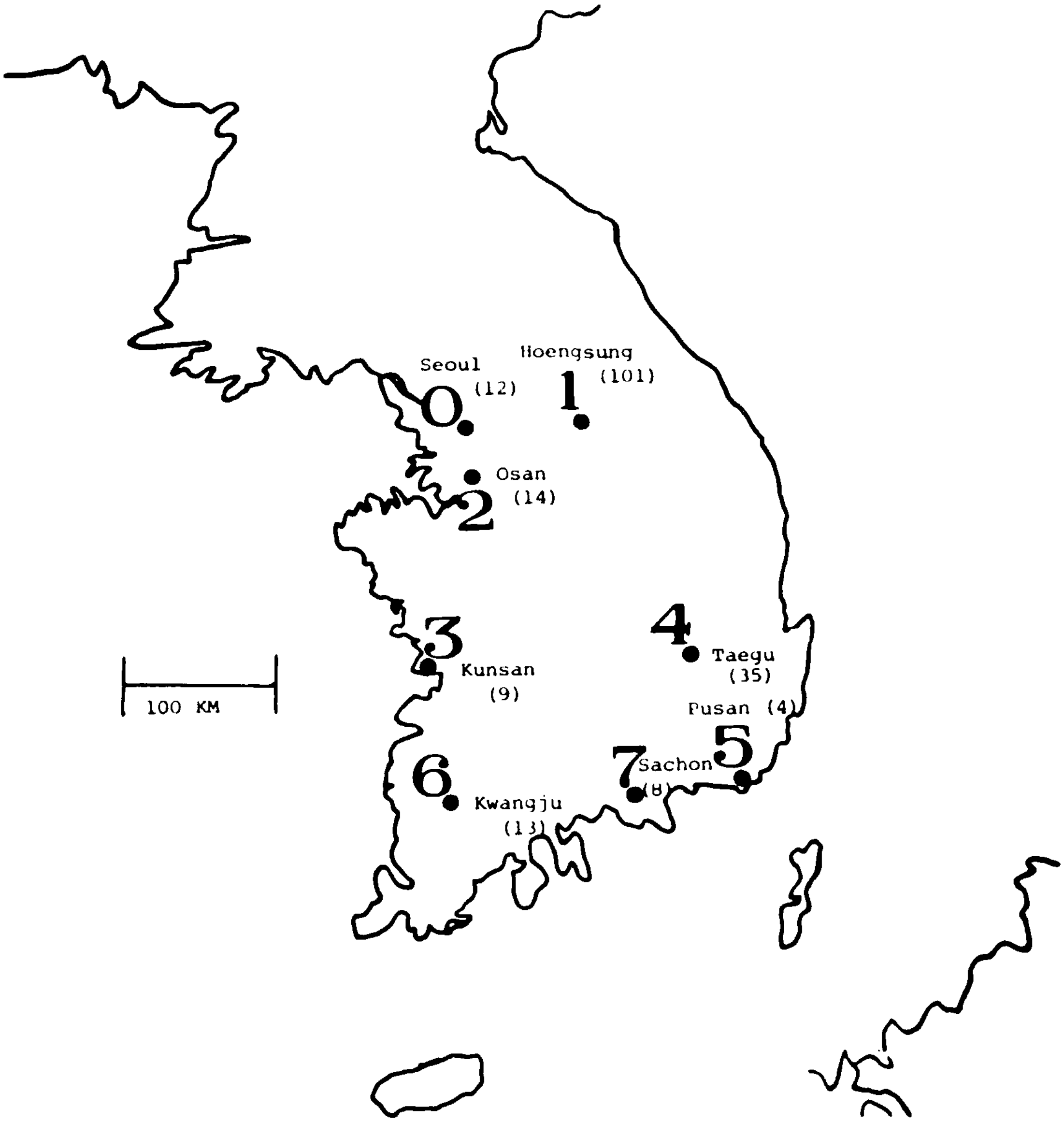
SPATIAL AUTOCORRELATION

GERMANY - SUMMER

WEATHER CATEGORY

2





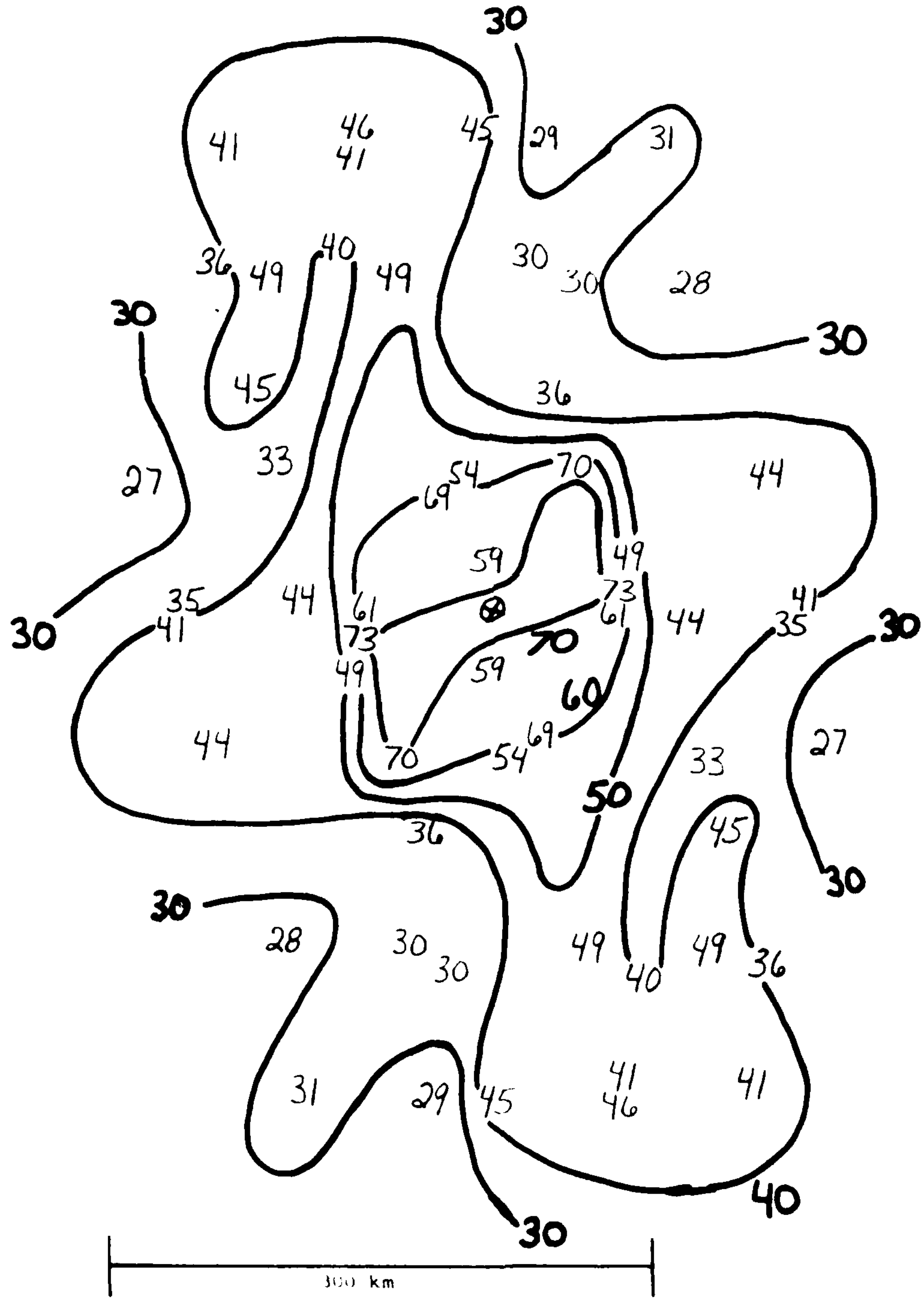
STATIONS IN KOREA. ELEVATION IN METERS IN PARENTHESES.

KOREA. STATION PAIRS

SPATIAL AUTOCORRELATION

KOREA - WINTER

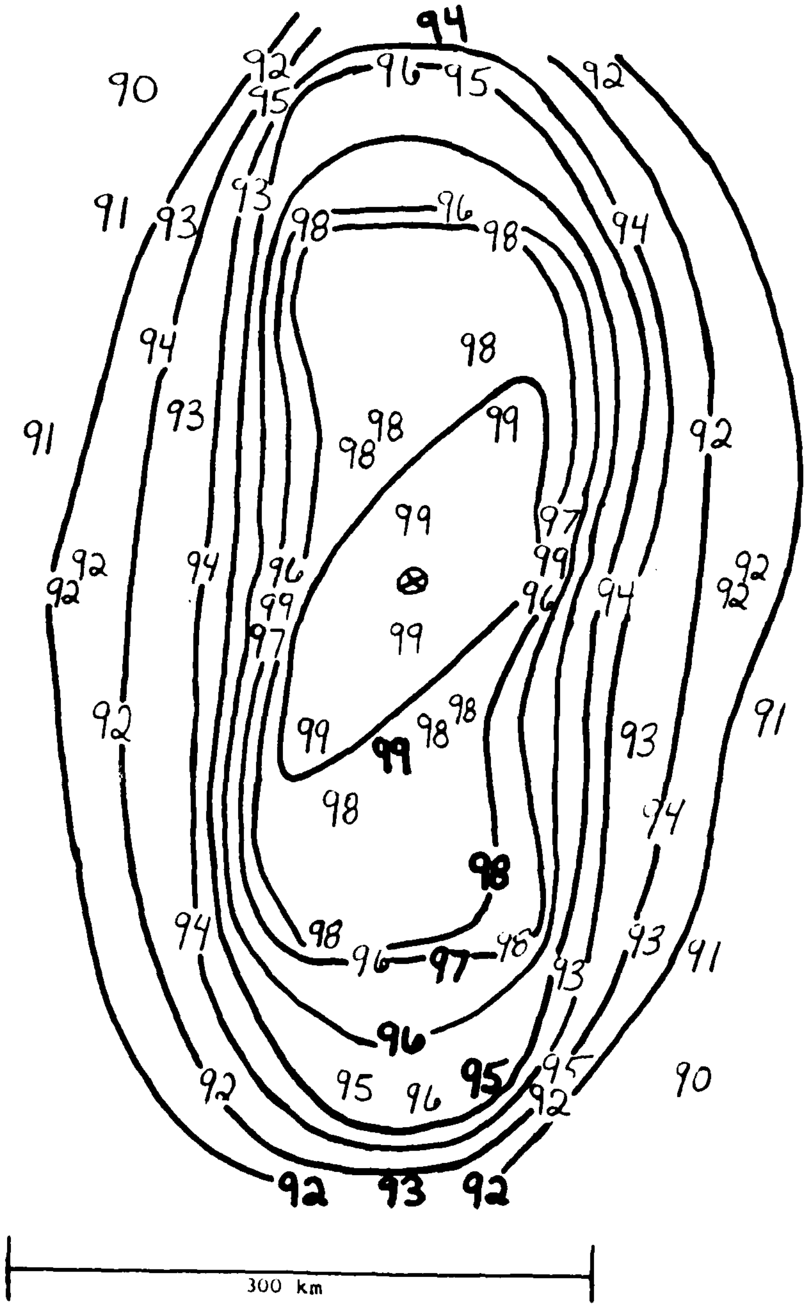
CEILING CATEGORY



SPATIAL AUTOCORRELATION

KOREA - WINTER

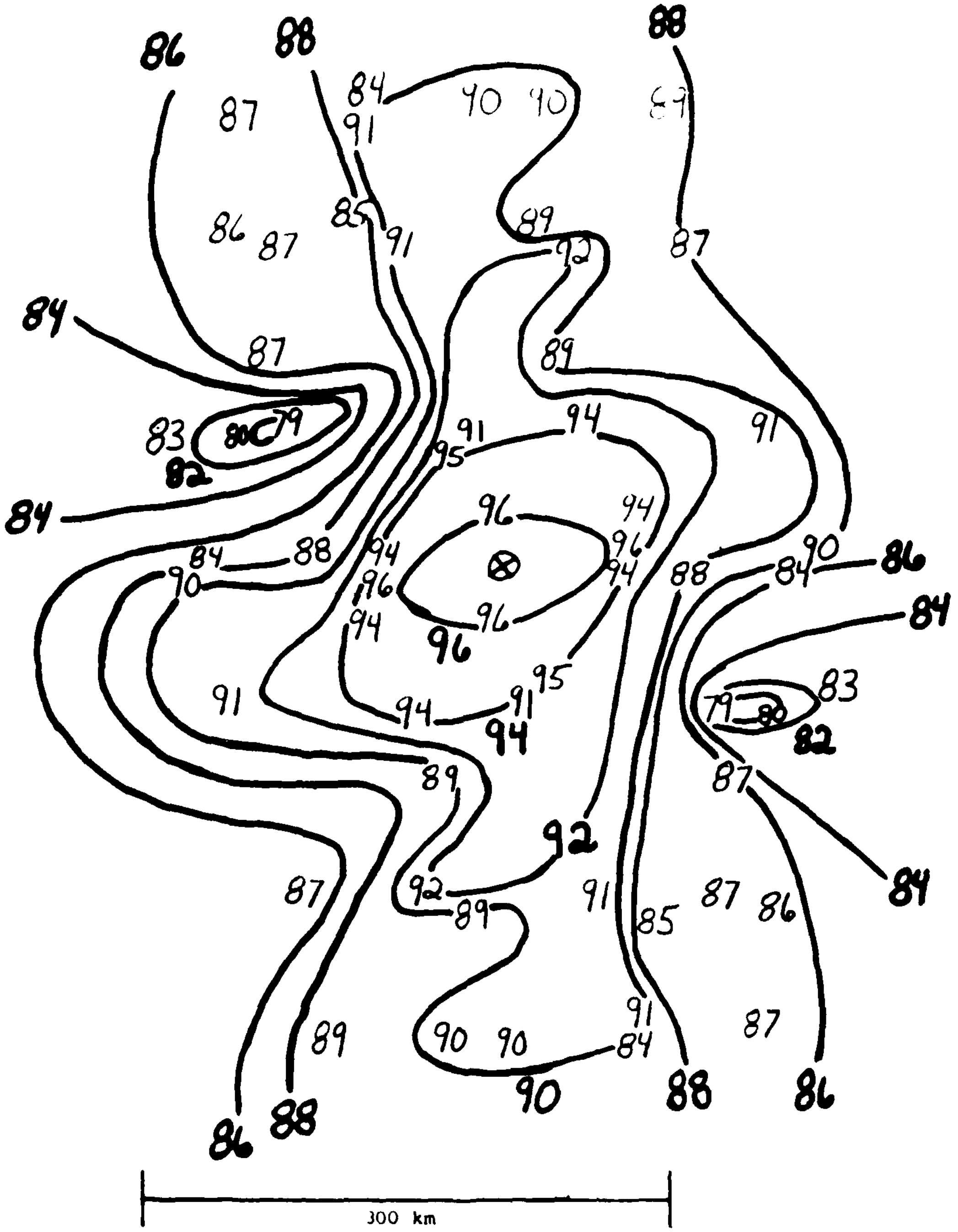
PRESSURE



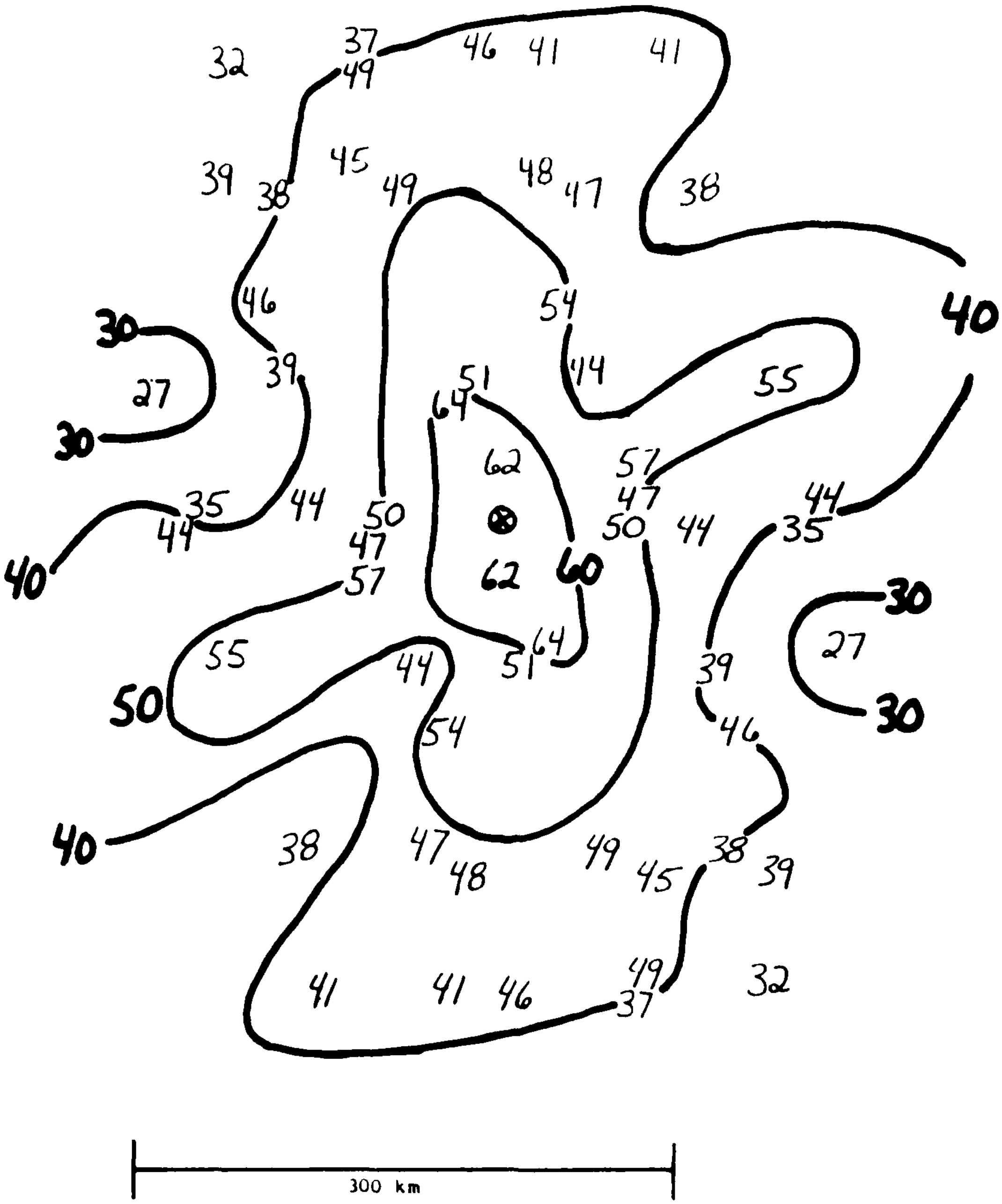
SPATIAL AUTOCORRELATION

KOREA - WINTER

TEMPERATURE



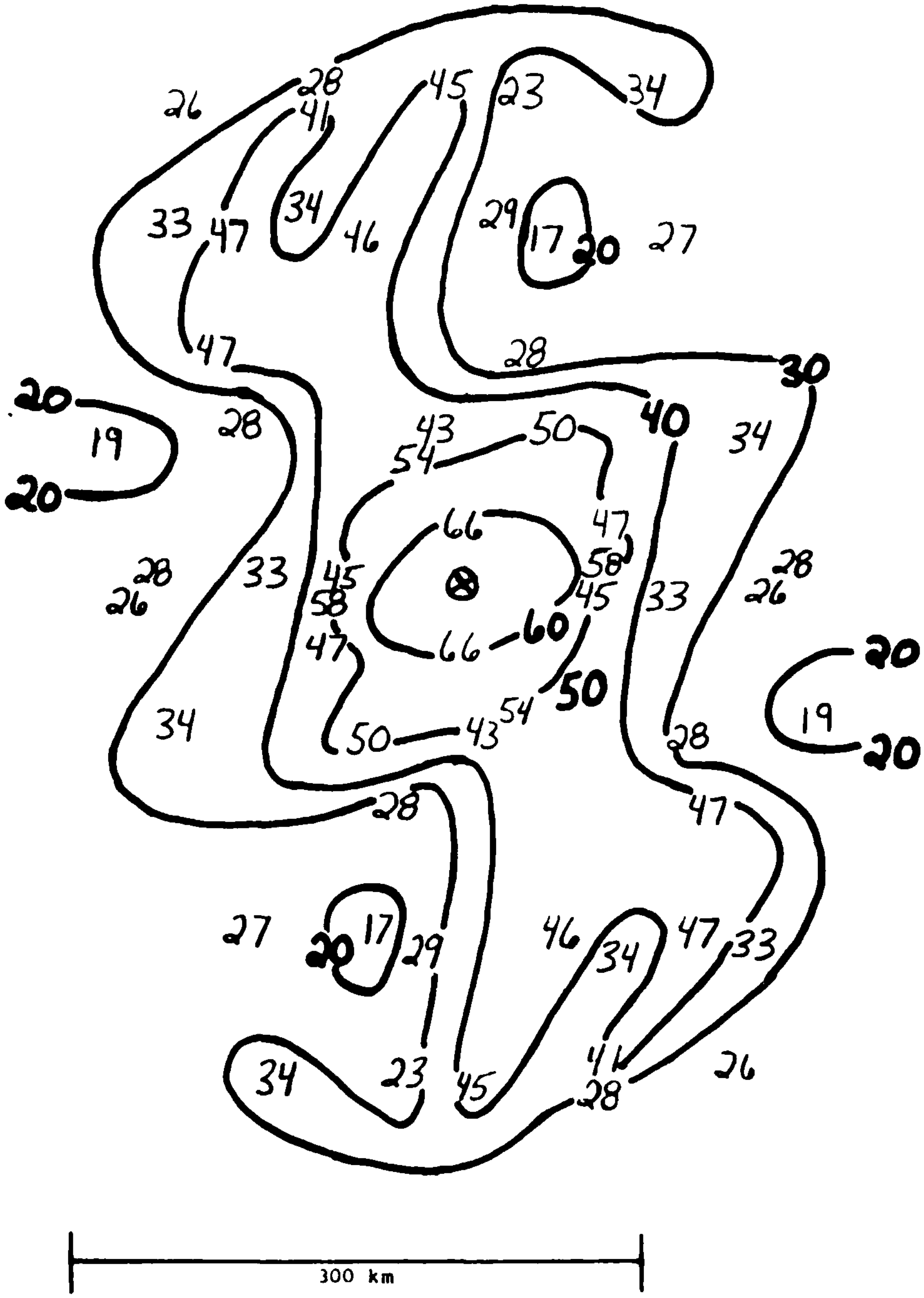
SPATIAL AUTOCORRELATION
KOREA - WINTER
WIND SPEED



SPATIAL AUTOCORRELATION

KOREA - WINTER

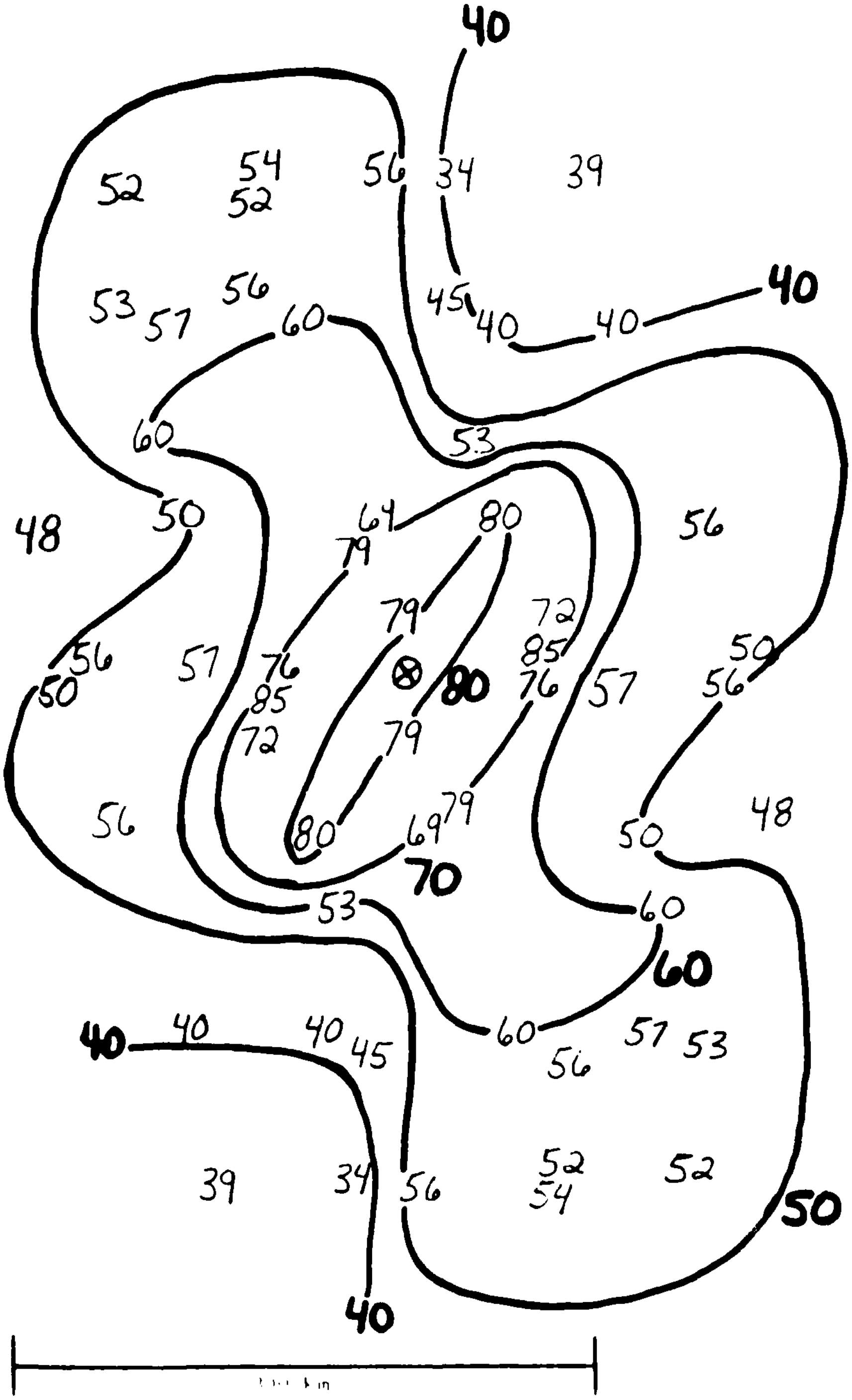
VISIBILITY



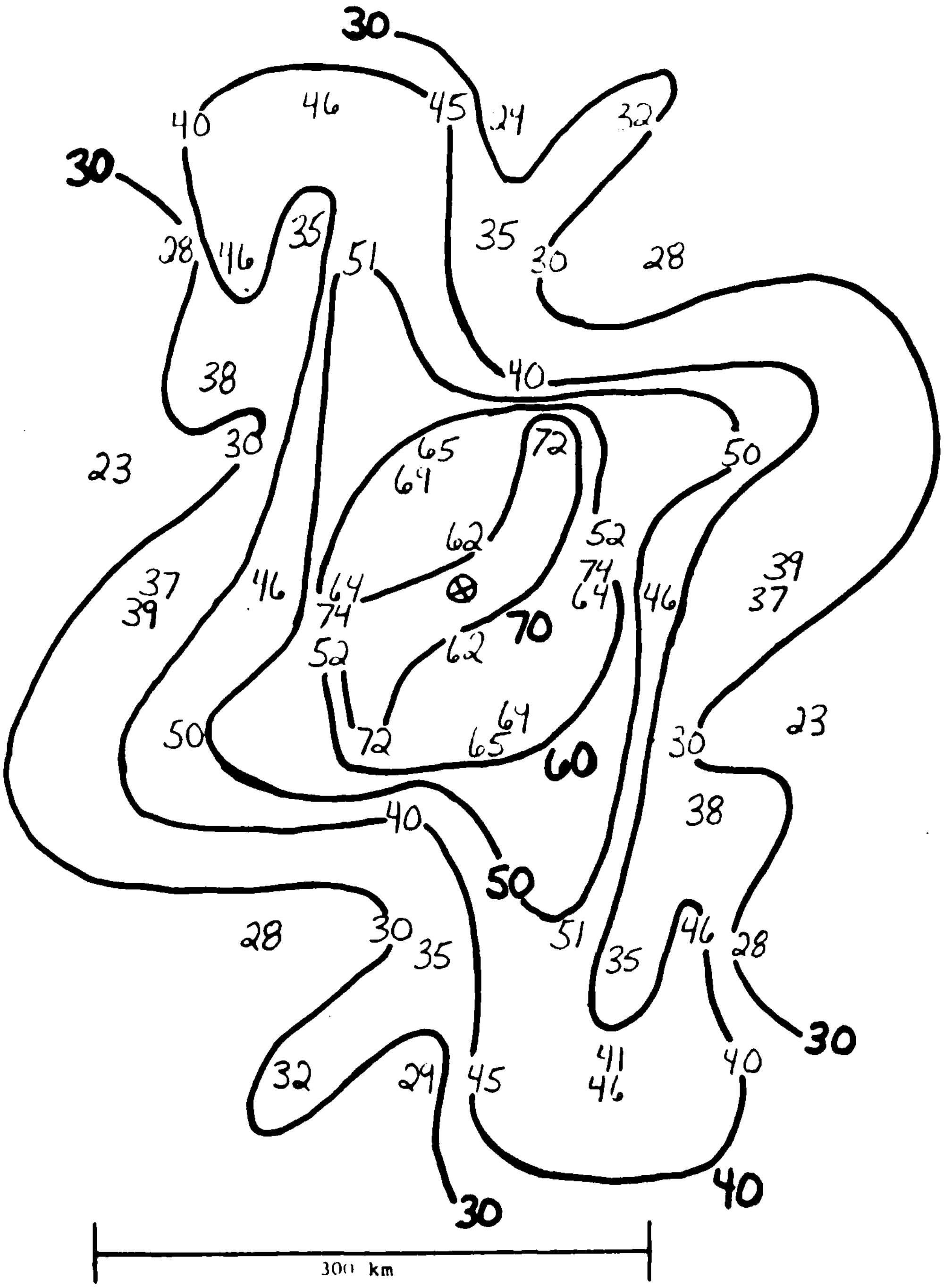
SPATIAL AUTOCORRELATION

KOREA - WINTER

TOTAL CLOUD COVER



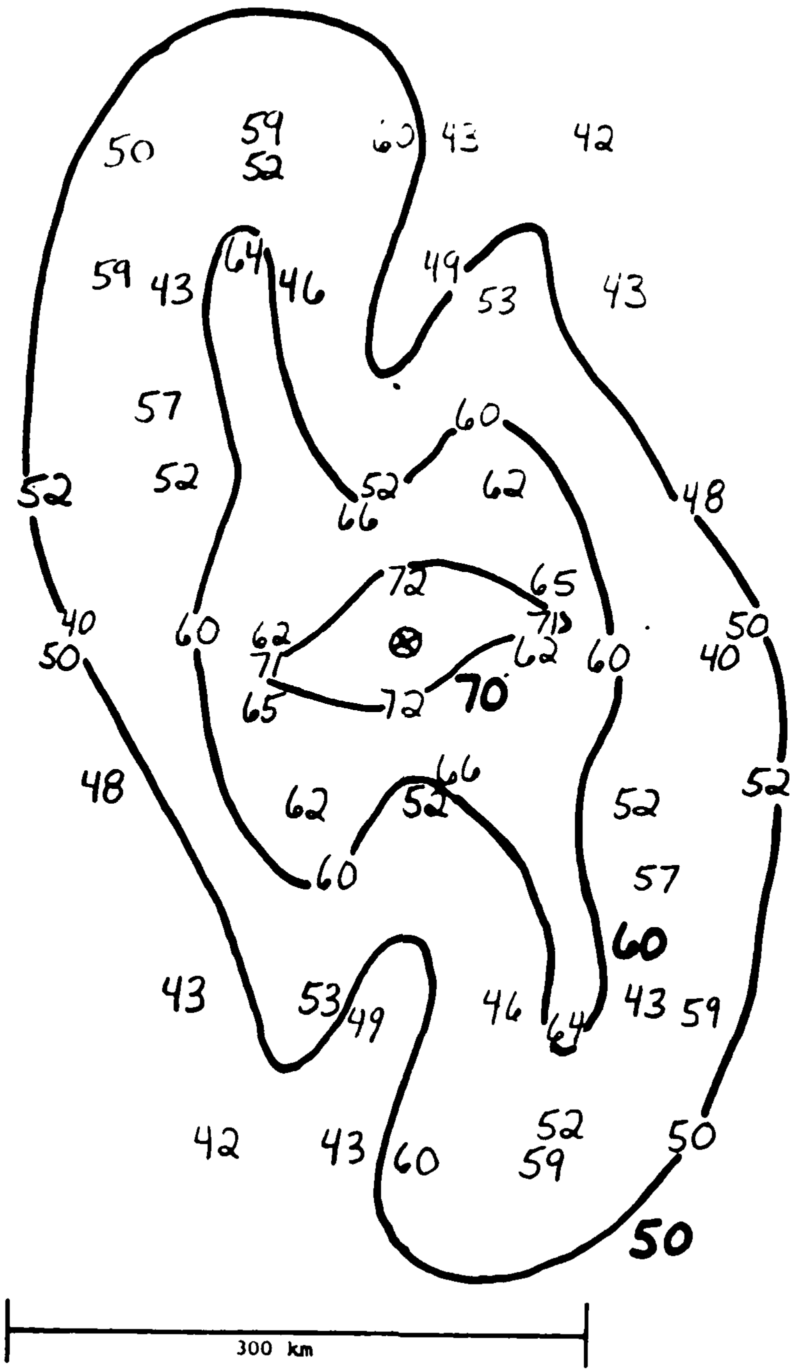
SPATIAL AUTOCORRELATION
KOREA - WINTER
LOW CLOUD AMOUNT



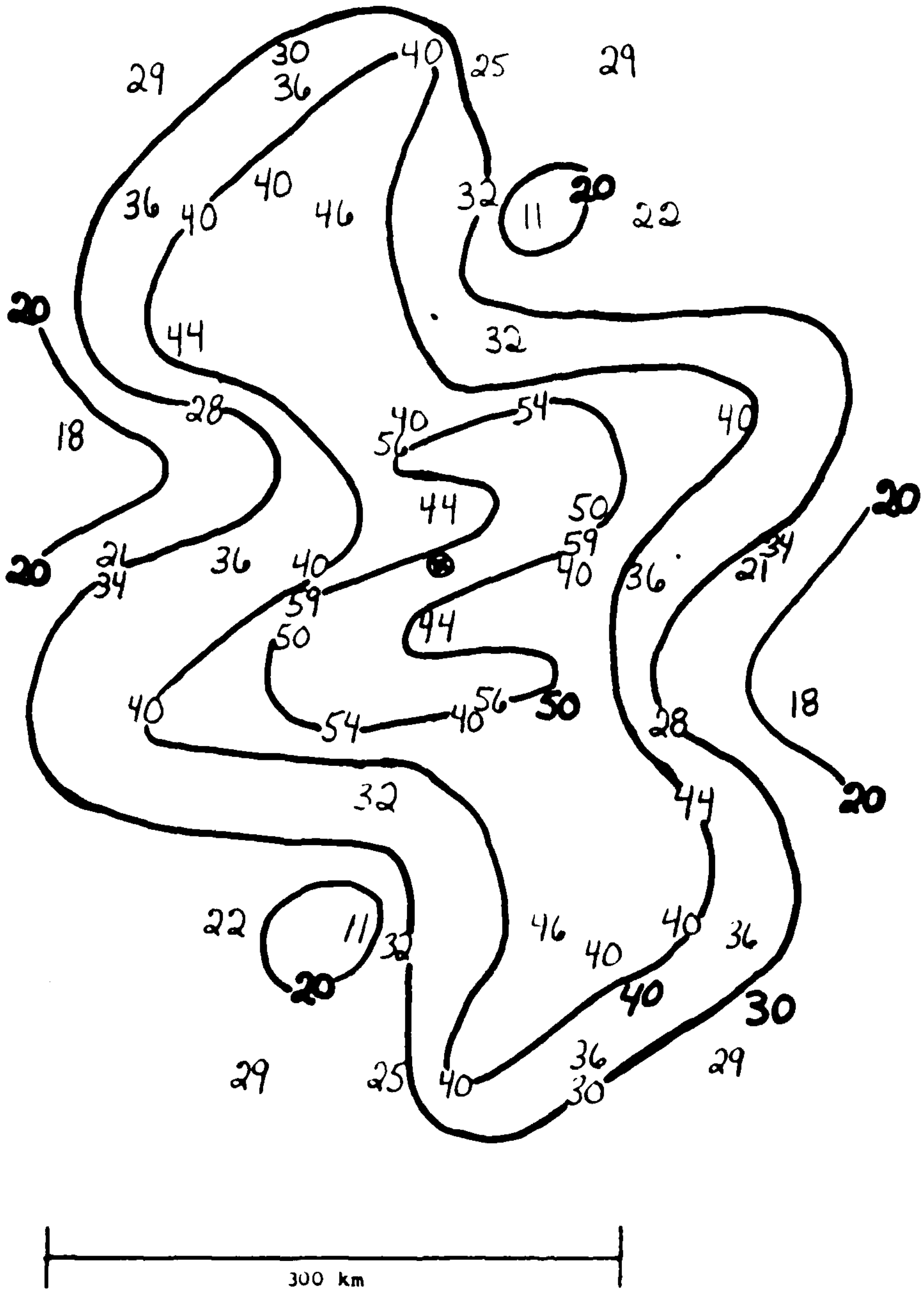
SPATIAL AUTOCORRELATION

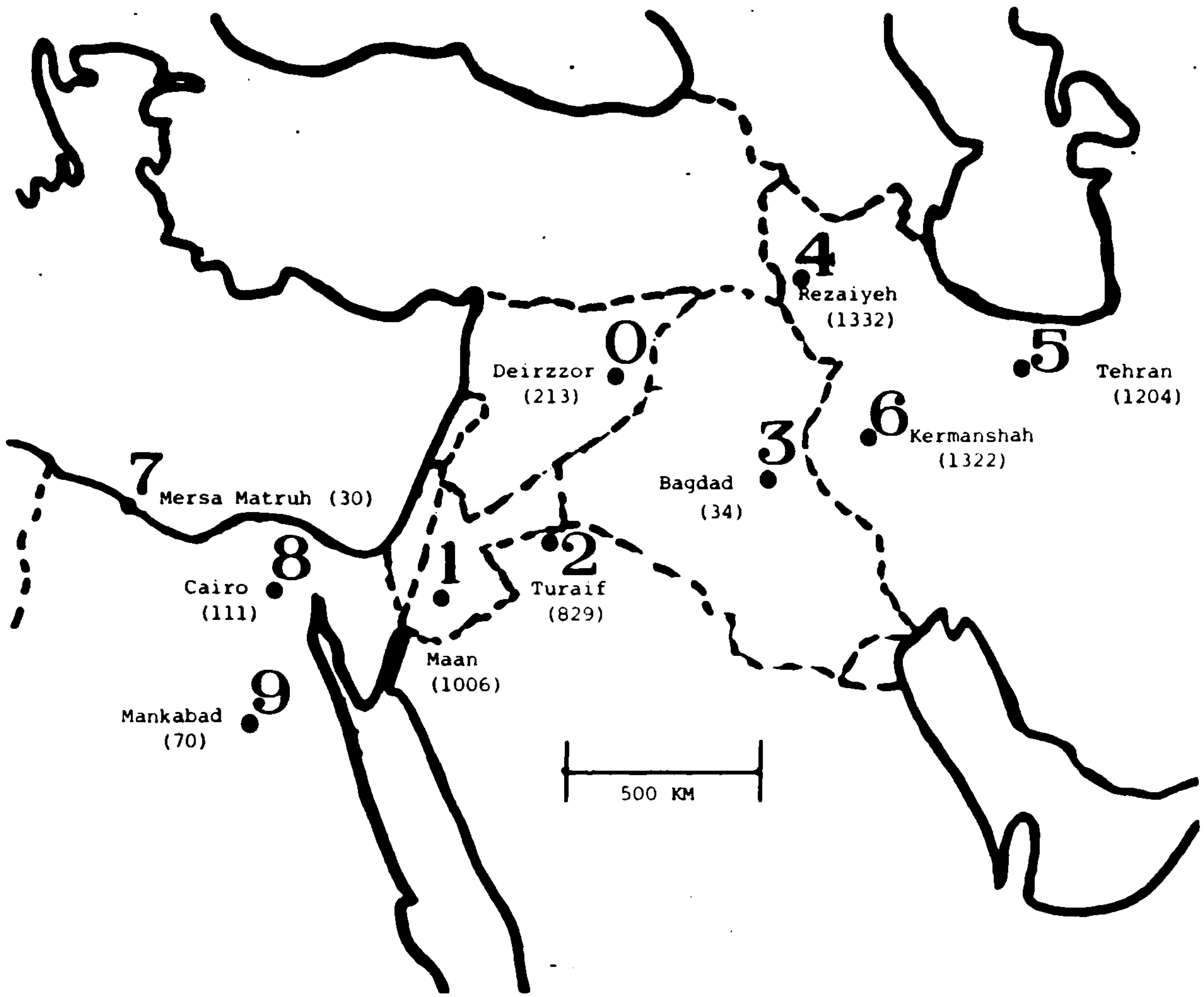
KOREA - WINTER

RELATIVE HUMIDITY

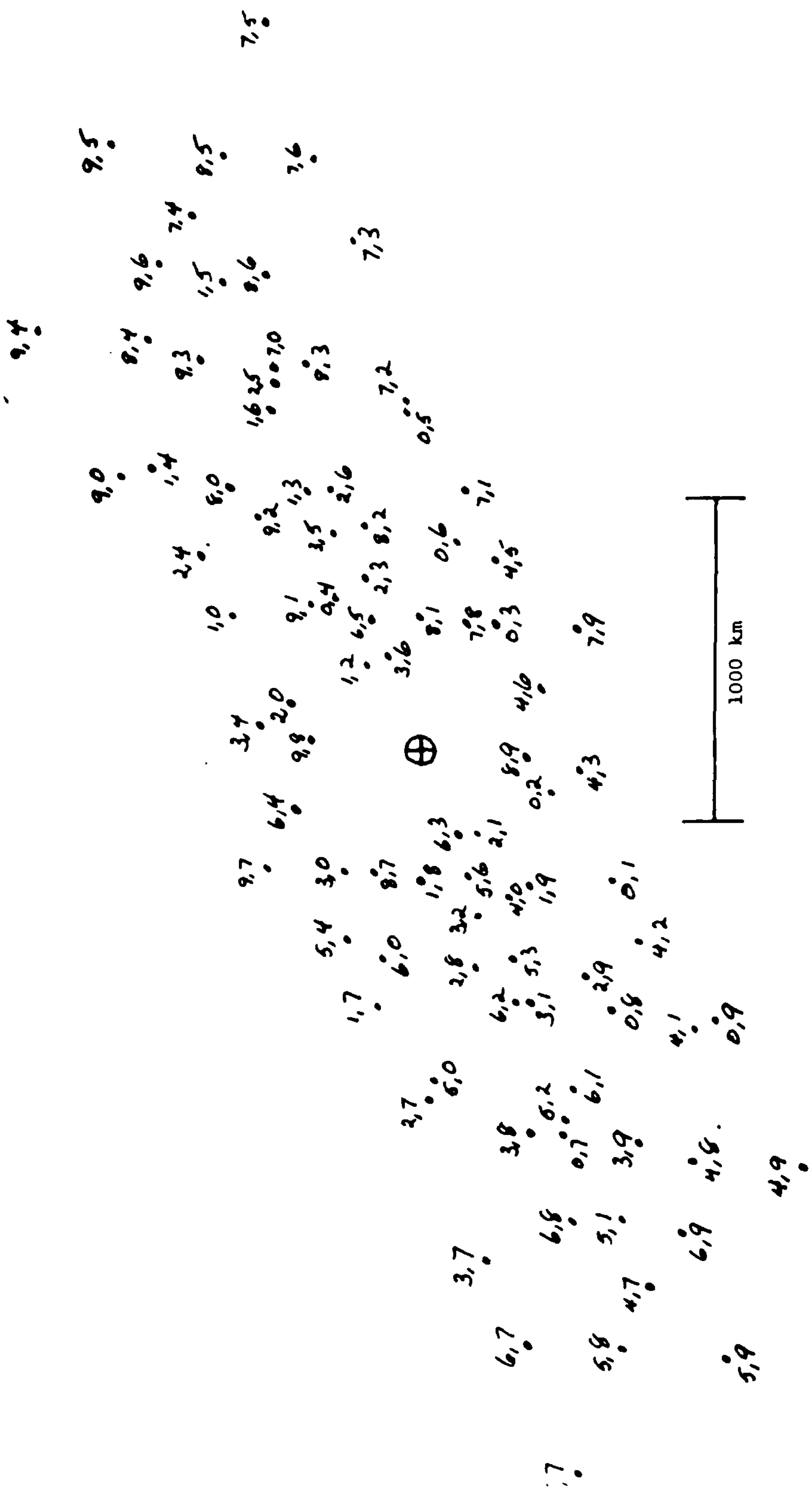


SPATIAL AUTOCORRELATION
KOREA - WINTER
WEATHER CATEGORY



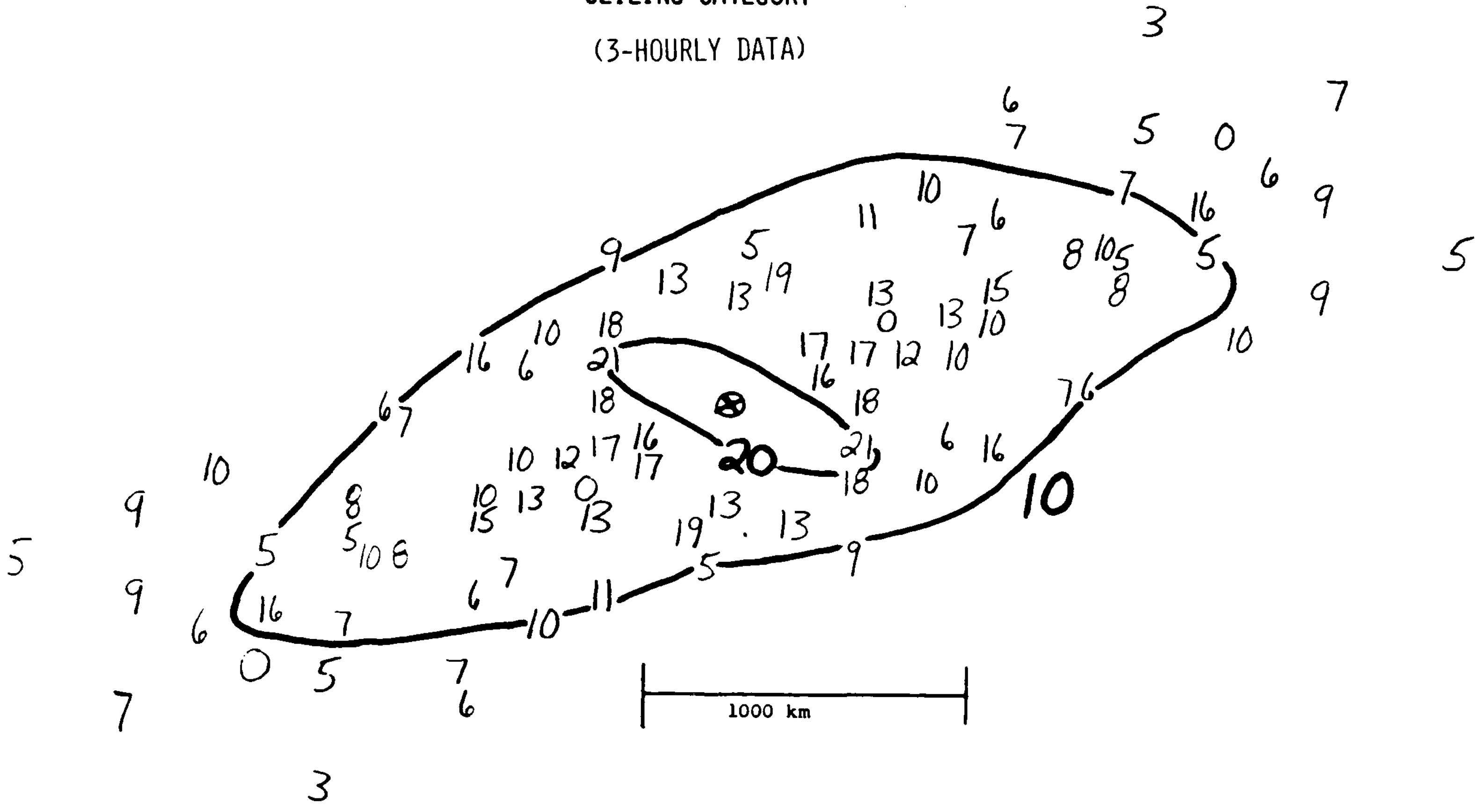


STATIONS IN SOUTHWEST ASIA. ELEVATION IN METERS IN PARENTHESES.



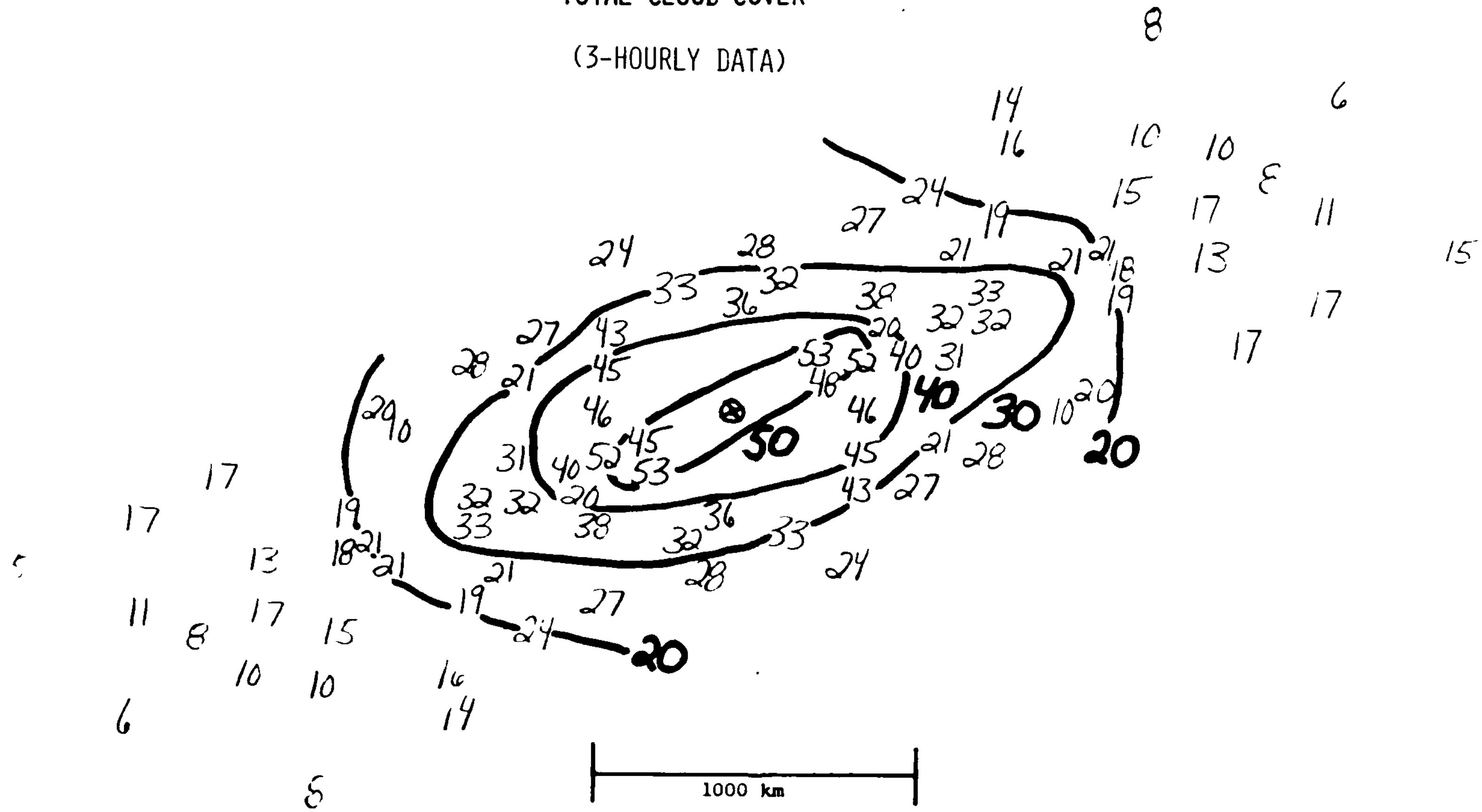
SOUTHWEST ASIA. STATION PAIRS

SPATIAL AUTOCORRELATION
SOUTHWEST ASIA - WINTER
CEILING CATEGORY
(3-HOURLY DATA)

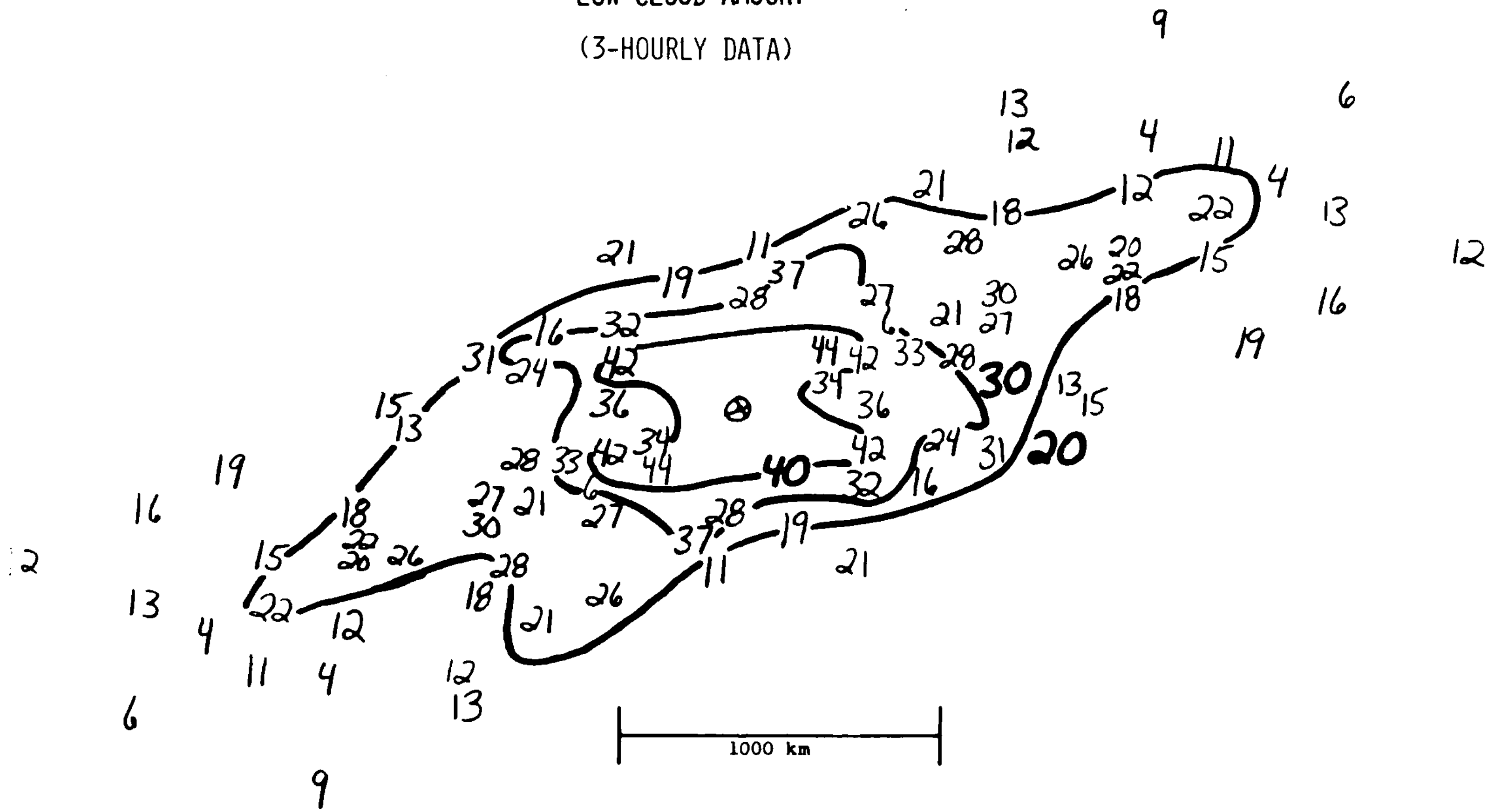


SPATIAL AUTOCORRELATION
SOUTHWEST ASIA - WINTER
TOTAL CLOUD COVER

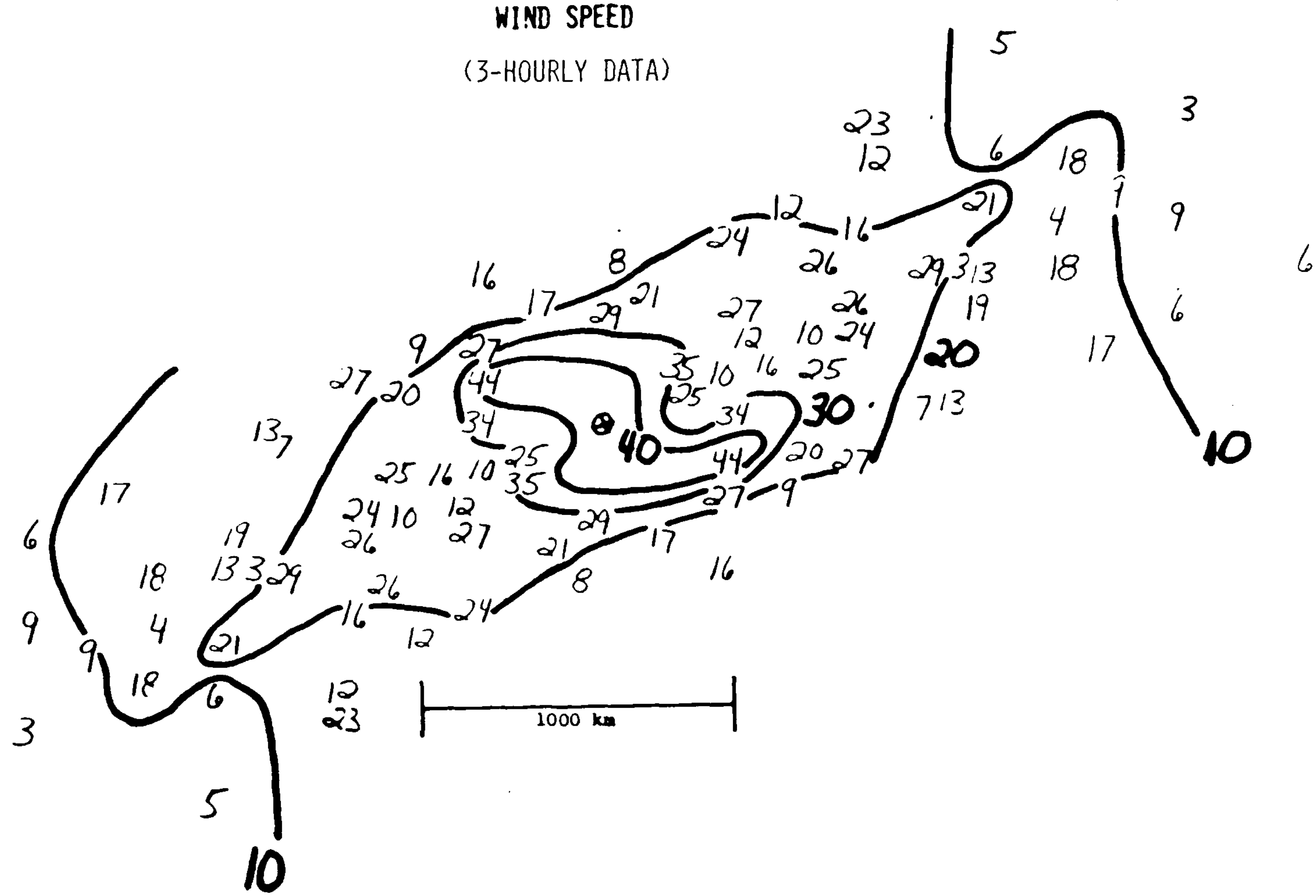
(3-HOURLY DATA)



SPATIAL AUTOCORRELATION
SOUTHWEST ASIA - WINTER
LOW CLOUD AMOUNT
(3-HOURLY DATA)

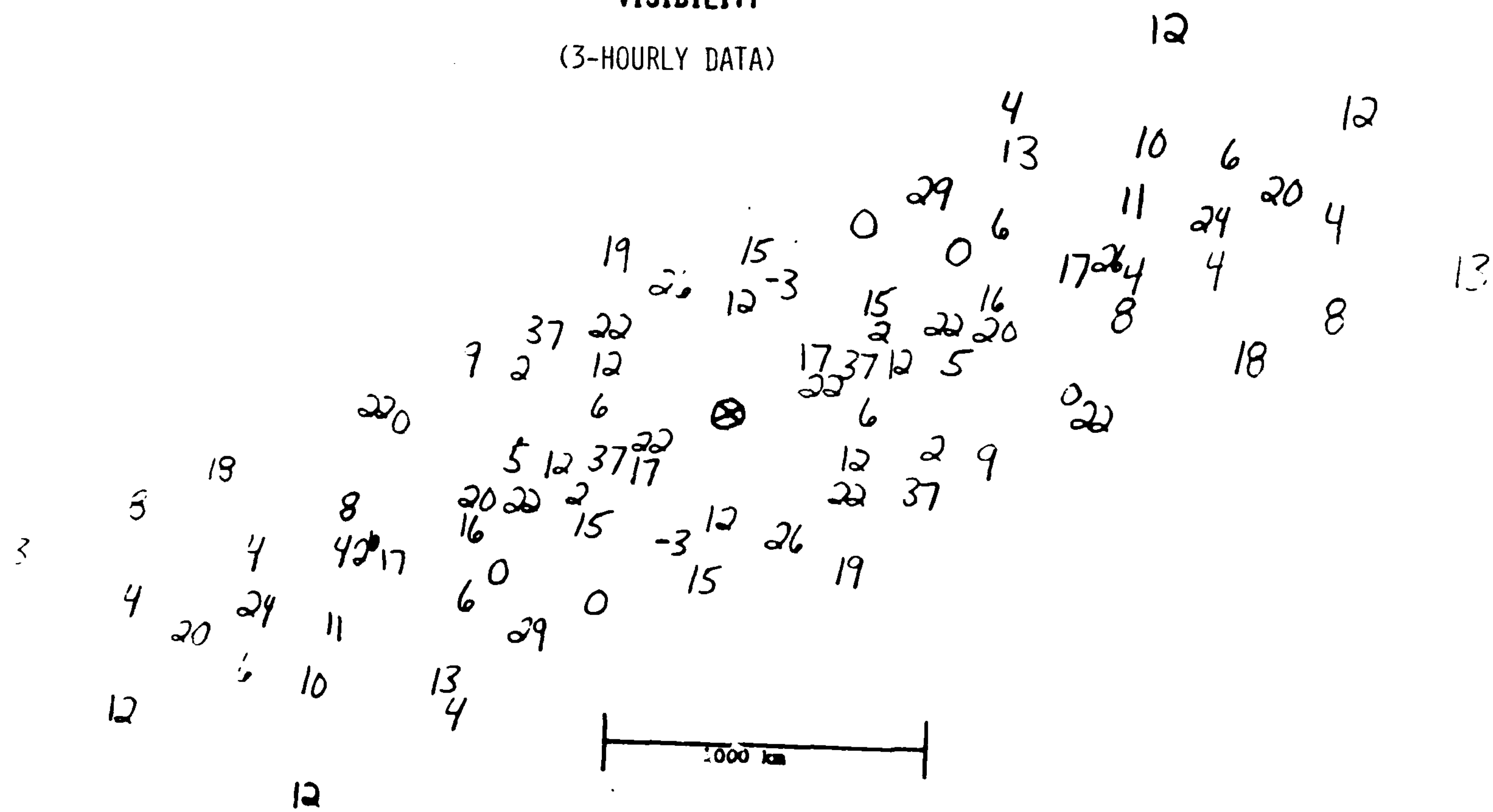


SPATIAL AUTOCORRELATION
SOUTHWEST ASIA - WINTER
WIND SPEED
(3-HOURLY DATA)

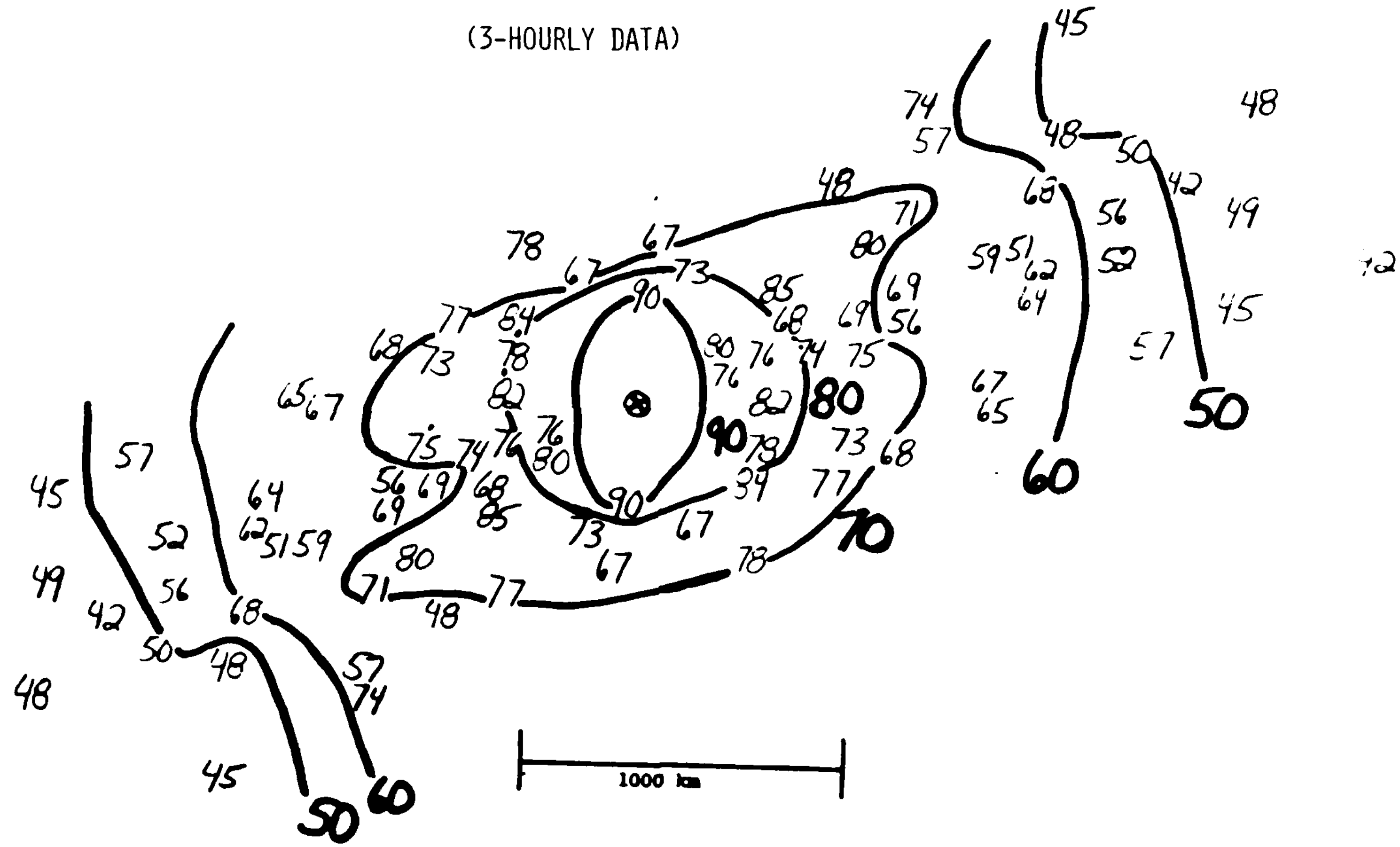


SPATIAL AUTOCORRELATION
SOUTHWEST ASIA - WINTER
VISIBILITY

(3-HOURLY DATA)

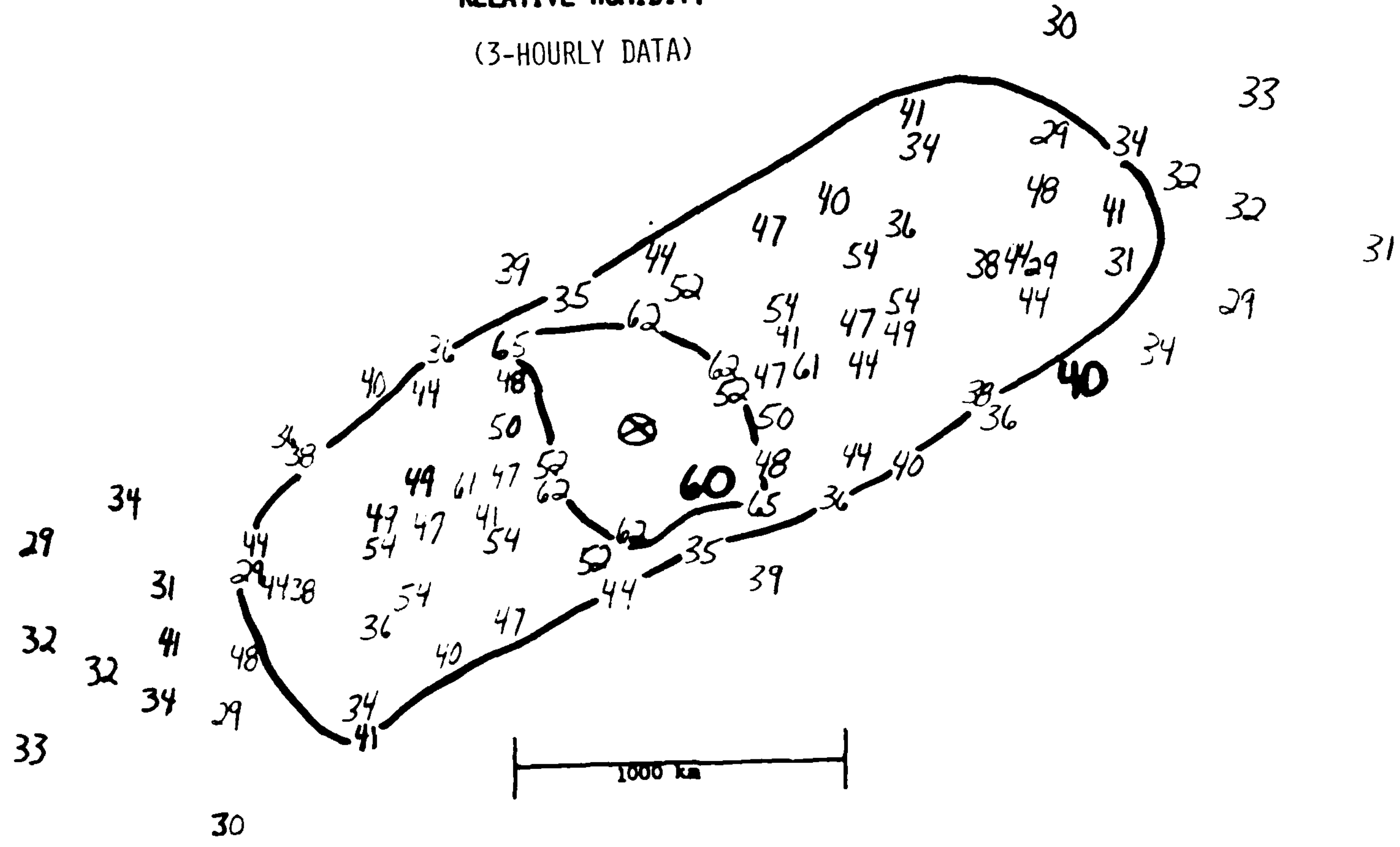


SPATIAL AUTOCORRELATION
SOUTHWEST ASIA - WINTER
TEMPERATURE
(3-HOURLY DATA)



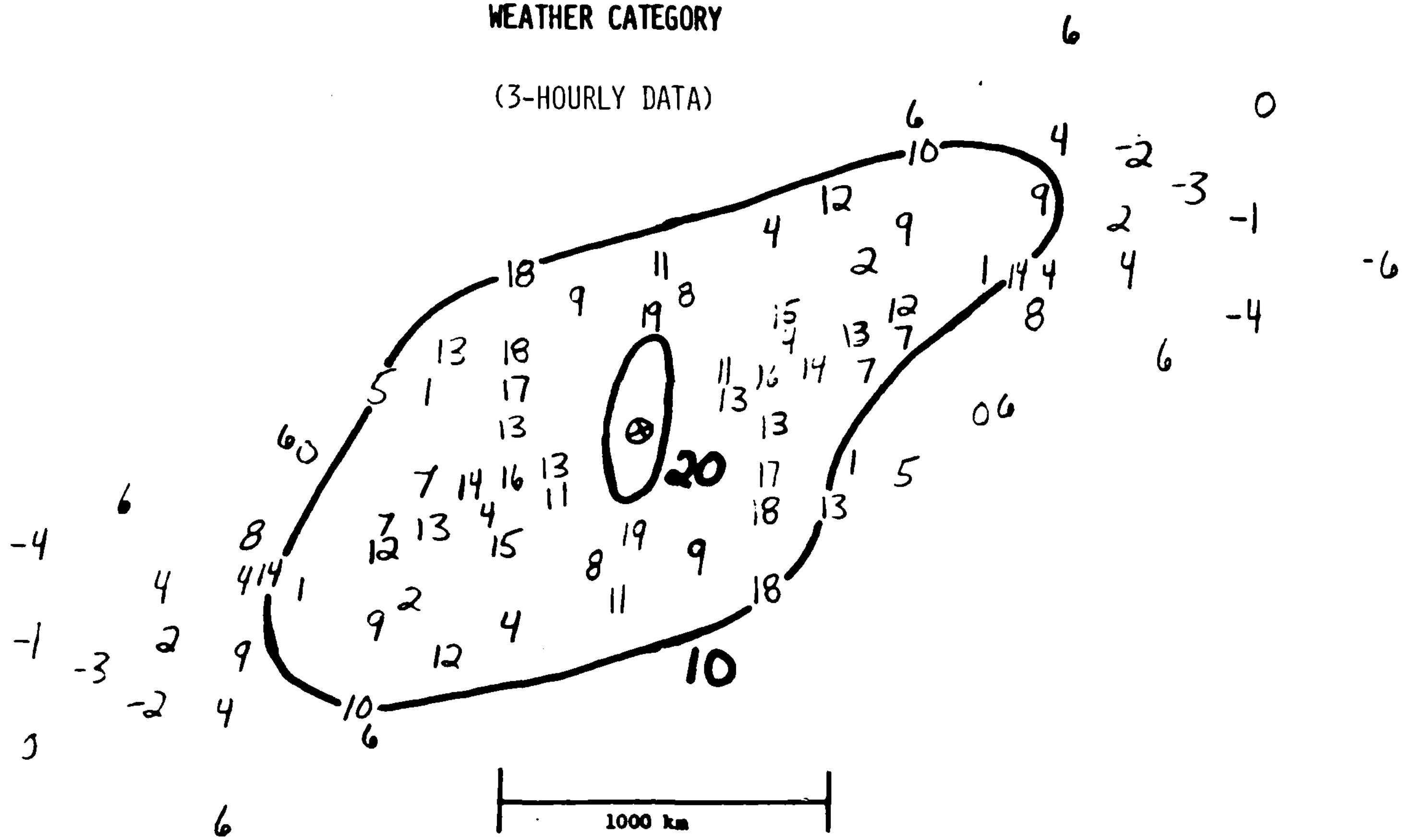
SPATIAL AUTOCORRELATION
SOUTHWEST ASIA - WINTER
RELATIVE HUMIDITY

(3-HOURLY DATA)



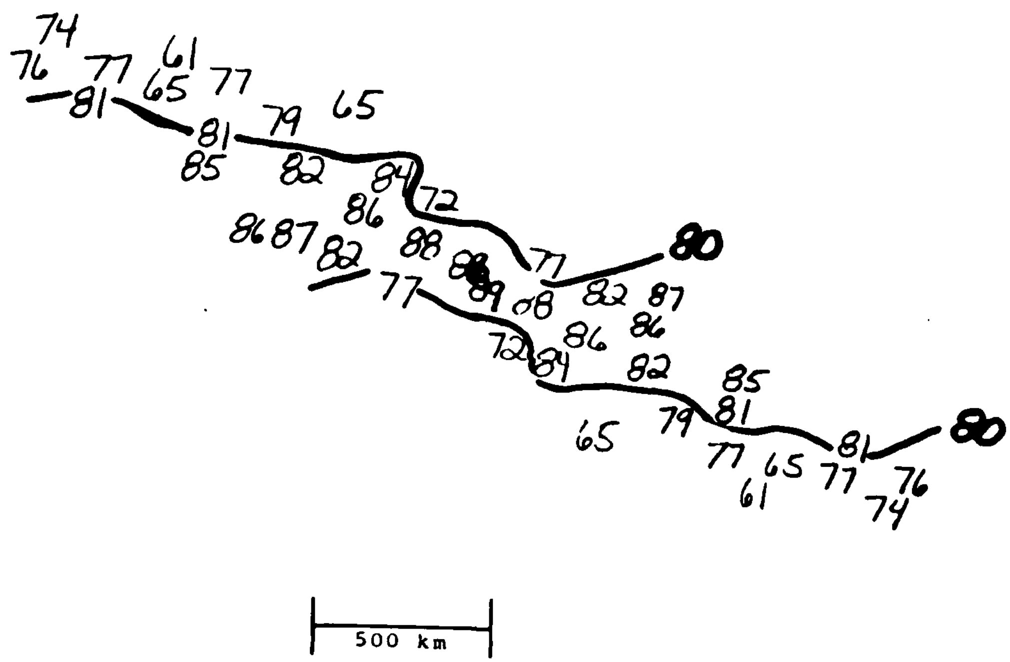
SPATIAL AUTOCORRELATION
SOUTHWEST ASIA - WINTER
WEATHER CATEGORY

(3-HOURLY DATA)

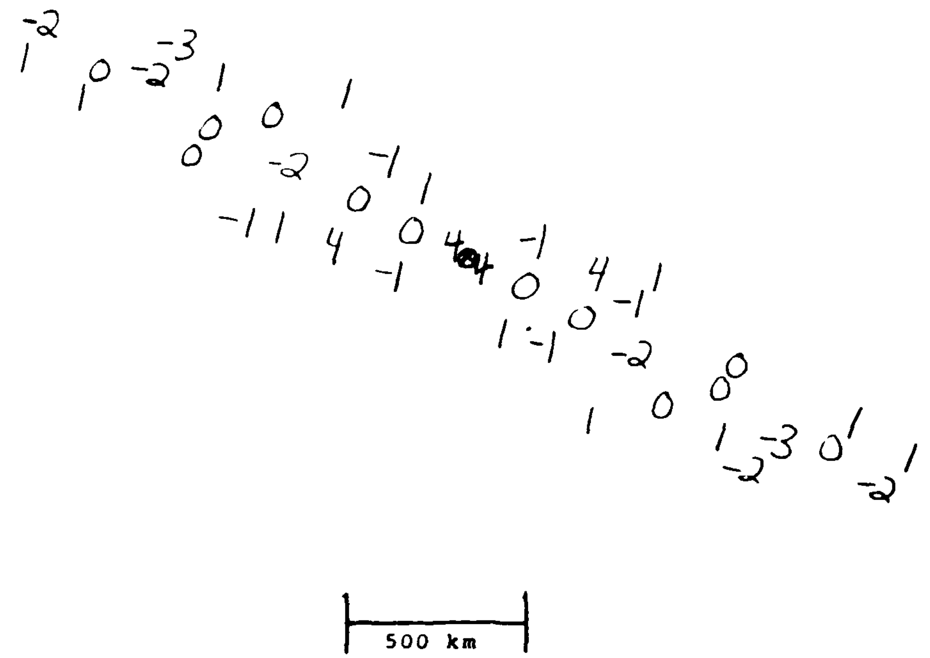


STATIONS IN CENTRAL AMERICA. ELEVATION IN METERS IN PARENTHESES.

SPATIAL AUTOCORRELATION
CENTRAL AMERICA - WINTER
TEMPERATURE



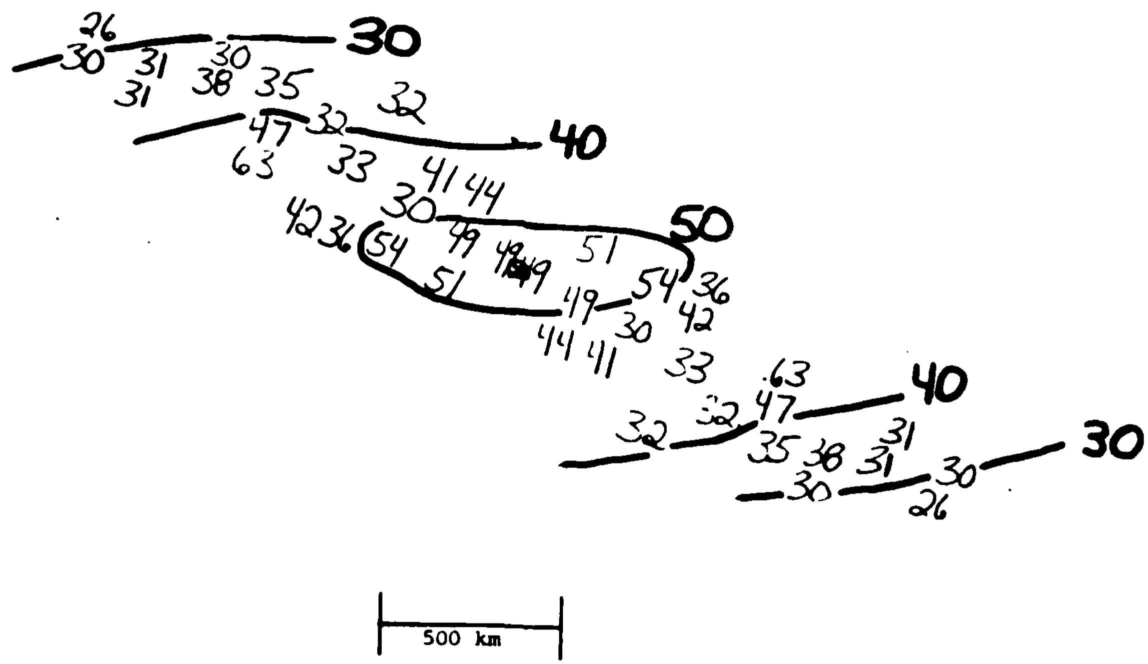
SPATIAL AUTOCORRELATION
CENTRAL AMERICA - WINTER
CEILING CATEGORY

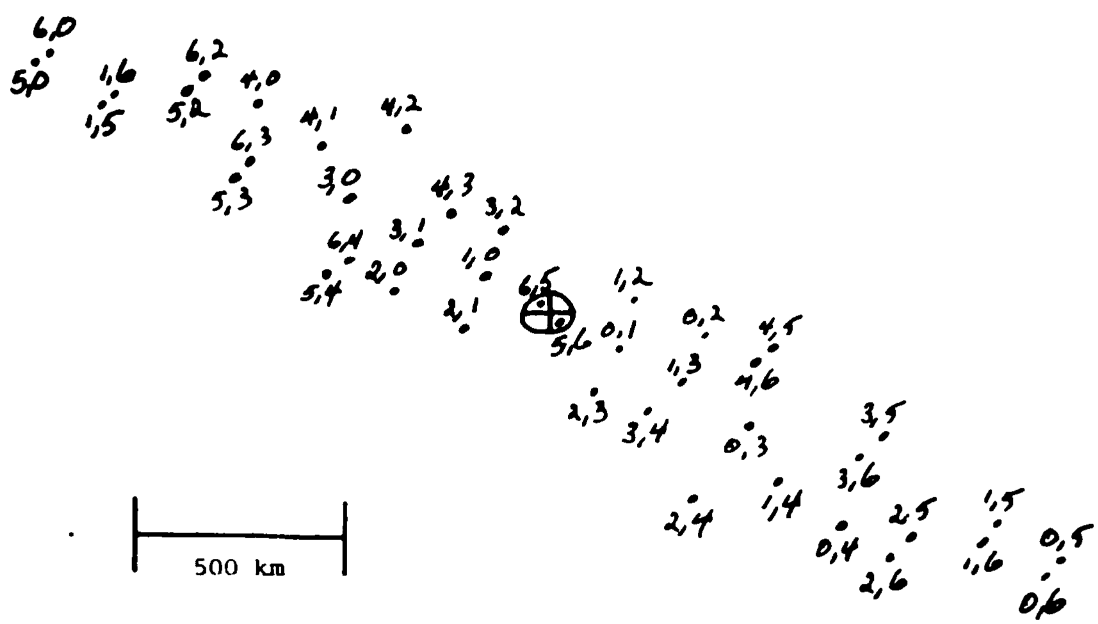


SPATIAL AUTOCORRELATION

CENTRAL AMERICA - WINTER

WIND SPEED



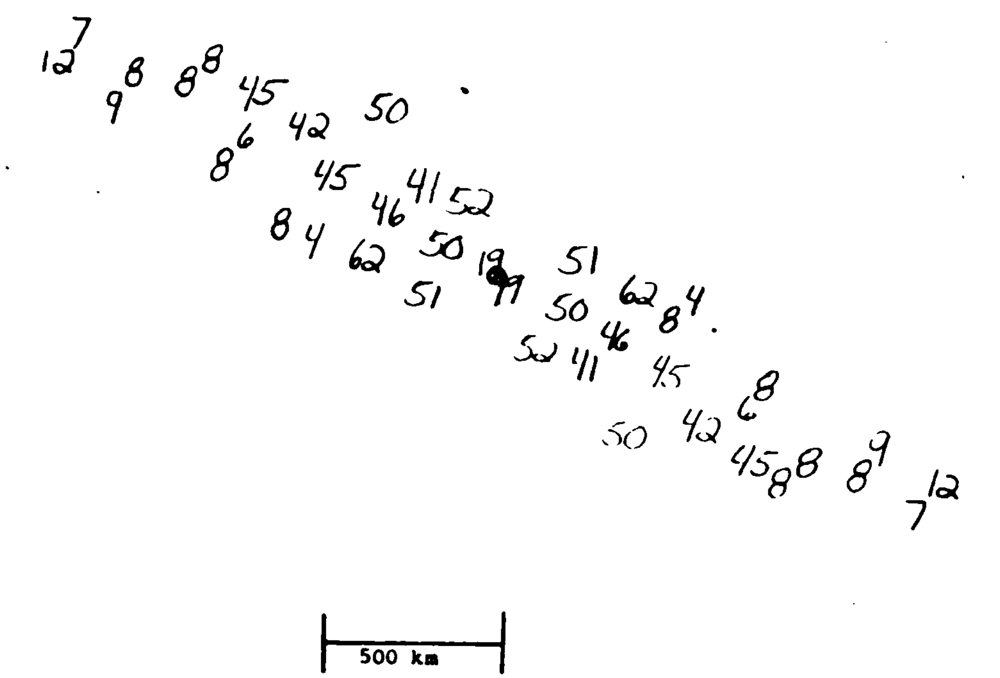


CENTRAL AMERICA. STATION PAIRS

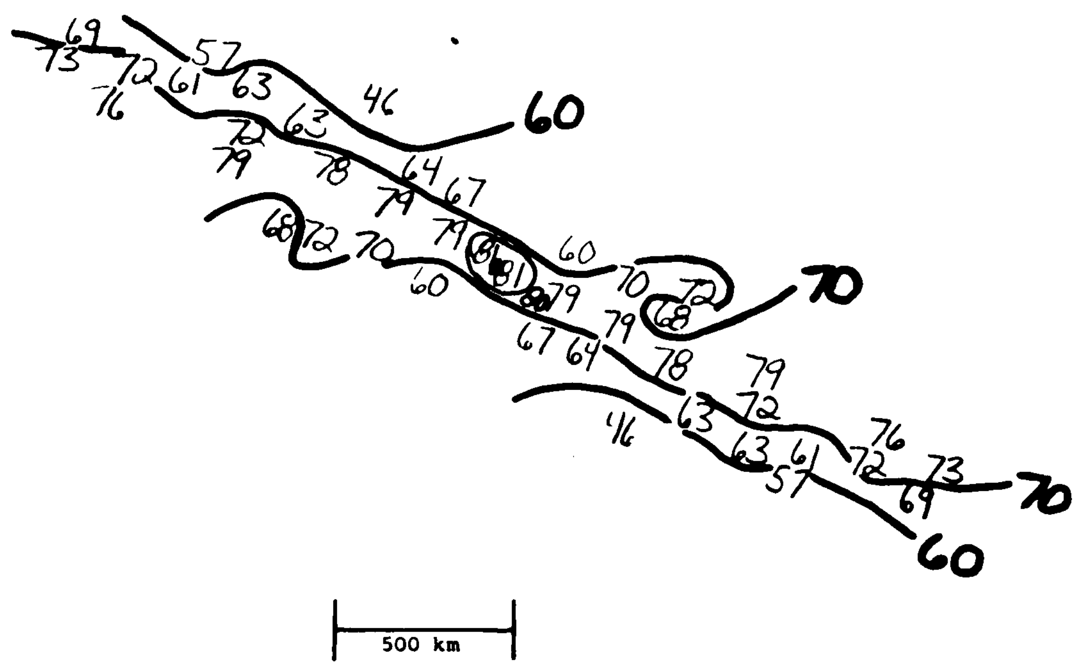
SPATIAL AUTOCORRELATION

CENTRAL AMERICA - WINTER

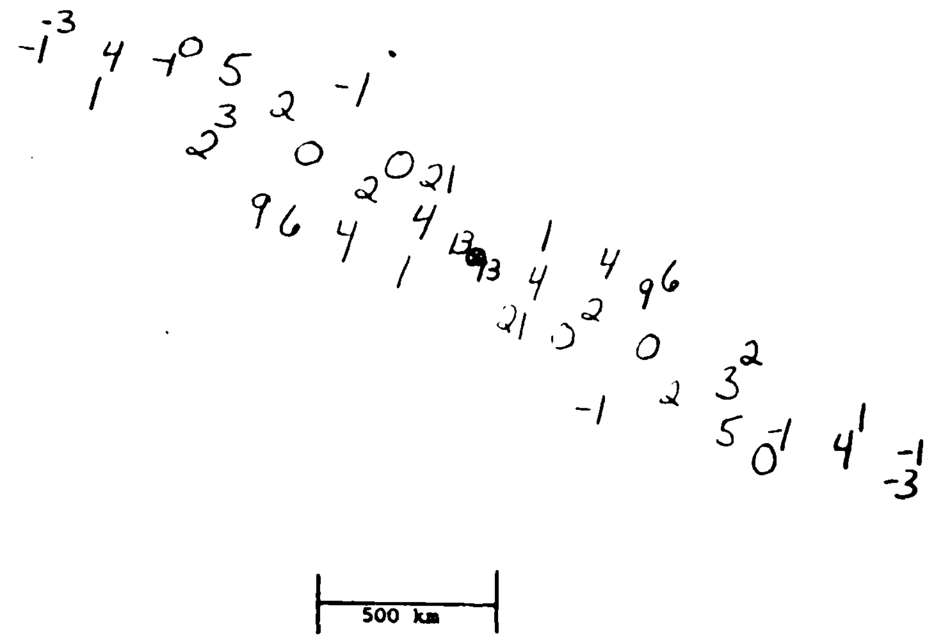
VISIBILITY



SPATIAL AUTOCORRELATION
CENTRAL AMERICA - WINTER
RELATIVE HUMIDITY



SPATIAL AUTOCORRELATION
CENTRAL AMERICA - WINTER
WEATHER CATEGORY



CLOUD AND VISIBILITY MODELING OF JOINT MESOSCALE PROBABILITY IN CENTRAL EUROPE

Oscar M. Essenwanger
U.S. Army Missile Laboratory
U.S. Army Missile Command

Cloud and Visibility Modeling of Joint Mesoscale Probability in Central Europe

By

Dr. Oskar M. Essenwanger
US Army Missile Laboratory
US Army Missile Command
Redstone Arsenal, Alabama 35898

1. This series of slides deals with the joint probabilities and areal persistence in the mesoscale in Central Europe (Letter Report RR-84-16).

2. After an introduction of the station locations and the cloud/visibiity classes used in this study (slides 1 and 2), slides 3-6 show a comparison of the period of record of the 10-year period 1966-76 with earlier periods. As expected, some climatic variations are displayed. The significance of the finding is the fact that 1966-76 is a time frame in which adverse weather (visibility-clouds) exhibits a smaller occurrence than during other periods of record. Thus, conclusions about the frequency of occurrence of adverse weather may underestimate the probability. In other climatological periods the chances may be higher. For more details, see reference 10.a.

3. The next slides (7-12) provide the maximum and minimum of the single station probabilities of adverse weather for the period 1966-76 and the diurnal variation in fall, winter, and November for two mesoscale areas. The fall and winter seasons and the month of November have been selected because they portray the seasons (months) with high frequency of adverse weather. More details can be found in references 10.a. and 10.b.

4. Slides 13 and 14 disclose the diurnal variation of adverse weather at single stations for fall. Slide 13 displays the occurrence of fog (visibility $\leq$ 1 km) and slide 14 provides a comparison of the probabilities for ceiling $<$8000 ft alone (second columns under station) and the contribution by the additional requirement that the visibility $>$ 5 miles (first columns under stations). These two slides show the basic conditions for evaluating the reductions of joint probabilities and the area persistence for the mesoscale study (for more details see references 10.a. and 10.b.).

5. Slide 15 exhibits the joint probabilities of two stations for fall. The stations are arranged in order of distance; SA-HA are only 40 miles apart and SA-FR have the largest distance with 90 miles. Again, the two columns under one station pair represent the joint probability for the most stringent requirements ceiling $<$8000 feet (second column) and ceiling $<$ 8000 feet and/or visibility $<$ 5 miles (first column). These numbers reflecting the percentage of joint occurrence of adverse weather are important in some applications. They do not provide, however, information about the areal persistence which is presented in the next series of slides.

6. The areal persistence could be studied by calculation of the linear correlation coefficient of adverse weather between two stations. Besides the difficulty in interpretation of the linear correlation coefficient of cloud amounts because of their "U-distribution," other problems exist. Ordinary calculations of the linear correlation coefficient are restricted to the total set of data of two stations without permitting evaluation of the vertical

structure. Another problem is the expansion to include more stations by use of the multiple correlation coefficient, which is determined with reference to one key station. Again, it is unsuitable to show the vertical structure. Thus this author decided to utilize the 2X2 contingency table as the basis and calculated the tetrachoric correlation. The technical details are given in slide 16. Since our data sample comprises $N \simeq 1000$, the 5% significance threshold of the correlation is $r = 0.055$. Any value higher than the threshold must be considered different from zero, although the magnitude of the correlation may not be of great practical value unless it is at least $r > 0.3$. It should be noted that $r = 0$ if in the contingency table the field $a = R_1 S_1$, where R_1 and S_1 (marginal distribution) are the probabilities of the occurrence of adverse weather (or ceiling alone) at station one or two, respectively.

7. Slides 17 and 18 display areal correlations of two station combinations in fall. This season was selected for its highest probabilities of fog (see references 10.c., d. and e.), but the other seasons disclose little change of the principal features of areal persistence, although the actual correlations may differ slightly. The two station correlation of areal persistence decreases with distance as expected, but scatter around the general trend of decrease. For fog (visibility ≤ 1 km, slide 17) the lowest areal persistence appears in the afternoon hours. The maximum occurs in the morning hours only for the larger distances, while closer stations show a maximum areal persistence in the late evening hours.

The vertical structure is evident from slide 18. It can be deduced that low ceiling and fog are localized phenomena with limited areal persistence, and the joint probabilities correspond to random coincidence. However, clouds with ceiling above 8000 feet can be accounted for in a widespread area in the mesoscale. This implies also that probably cirrus clouds (ceiling $> 15{,}000$ feet) have the highest area persistence. These findings agree with general expectations from knowledge about characteristics of synoptic phenomena in the mesoscale.

8. The three station areal persistence for fall is found in slides 19 and 20. The joint probability for two close stations (slide 19) and largest distance (slide 20) was chosen. Correlation coefficients of all hours were averaged. In slide 20 the maximum correlation was added, selected irrespective of the hour of the day. As indicated, the lower the ceiling or visibility the smaller the area persistence. This implies that the addition of a third station can reduce the joint probability of occurrence of adverse weather to virtually the minimum frequency as expected for independence. Only a small reduction of the adverse weather occurrence is gained if the conditions require ceiling > 2000 feet and visibility > 4 miles unless the two stations are a greater distance apart (slide 20).

9. Finally, slides 21-23 provide information on areal persistence in fall with four station combinations. The correlations in slide 21 are based on empirical probabilities for three stations and adding a fourth station. This fourth station is listed in the heading, i.e., the stations not listed in the column heading are the three stations of basic data. Again, the correlation coefficient has been averaged for all hours. Although the correlations vary for the individual combinations of stations, the general nature of the three station concept reappears. Low ceiling and visibility show only small area consistency, while clouds with ceiling ≥ 4500 feet provide the best area cover.

Slide 22 exhibits an alignment of two stations which can be considered as an evaluation of the relationship between East-West or North-South of the mesoscale area. In this mesoscale area the north-south persistence appears significantly higher than the west-east combination, but only for the conditions <4500 feet. Apparently the movement of clouds from west to east produces a more homogeneous field between the north and south part of the area in this particular case.

Finally, the diurnal variation of the areal persistence for the four stations is given in slide 23 for conditions of low ceiling and visibility and high ceiling and visibility of five miles requirement. The minimum persistence appears in the middle of the day at 10 to 13, except for the last column. Again, the highest persistence is found in the late evening hours or midnight.

10. References:

a. Essenwanger, O.M., and Larry J. Levitt, 1984: Joint Probability of Selected Cloud and Visibility Thresholds Around Frankfurt, Germany. US Army Missile Command, Redstone Arsenal, Alabama, Technical Report TR-RR-84-1, p. 82.

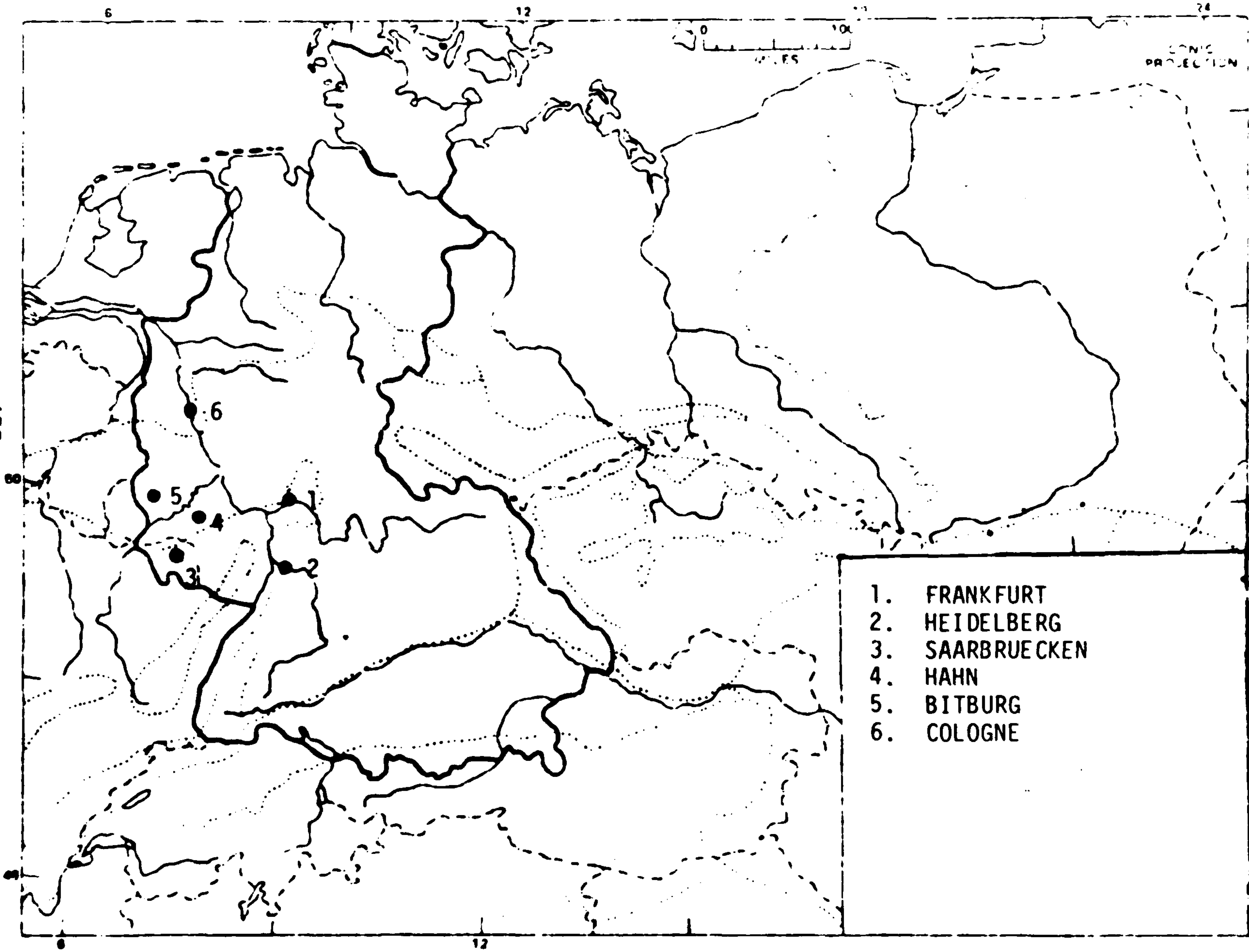
b. Essenwanger, O.M., and Larry J. Levitt, Joint Probability of Selected Cloud and Visibility Thresholds Around Koblenz, Germany. US Army Missile Command, Redstone Arsenal, Alabama, Technical Report TR-RR-84-3, p. 75.

c. Essenwanger, Oskar M., and Dorathy A. Stewart, 1976: Fog Climatology in Central Europe and Inferred Propagation Characteristics. Proceedings of the Optical-Submillimeter Atmospheric Propagation Conference, I, 165-179.

d. Essenwanger, Oskar M., and Dorathy A. Stewart, 1978: Fog and Haze in Europe and Their Effects on Performance of Electro-Optical Systems. Proceedings of the 1978 Army Science Conference, I, 425-439.

e. Stewart, D. A., and O. M. Essenwanger, 1982: A Survey of Fog and Related Optical Propagation Characteristics. Rev. Geophys. Space Phys., 20, 481-495.

LOCATION OF STATIONS



CLASSES OF ADVERSE WEATHER

- VISIBILITY $\leq$ 1 KM
- CEILING < 500 FT
- CEILING < 500 FT AND/OR VISIBILITY $\leq$ 2 MI
- CEILING < 800 FT
- CEILING < 800 FT AND/OR VISIBILITY $\leq$ 3 MI
- CEILING < 2000 FT AND/OR VISIBILITY $\leq$ 4 MI
- CEILING < 4500 FT AND/OR VISIBILITY $\leq$ 4 MI
- CEILING < 8000 FT AND/OR VISIBILITY $\leq$ 5 MI

2

COMPARISON OF ADVERSE WEATHER PROBABILITIES

(ANNUAL SUMMARY)

BITBURG

PERIOD OF RECORD (A) = 1952-1970; (B) = 1966-1975

	V ≤ 1 KM		C < 500 FT		C < 800 FT V ≤ 3 MI		C < 8000 FT V ≤ 5 MI	
HOUR	A	B	A	B	A	B	A	B
1	5.5	5.4	10.1	10.0	28.8	25.1	66.2	61.9
4	8.4	8.0	12.6	12.4	38.5	32.3	76.2	70.8
7	9.7	8.9	14.2	13.6	43.5	37.7	81.1	77.4
10	5.5	5.6	10.8	10.8	30.9	28.8	75.4	72.2
13	3.0	3.5	7.1	7.0	20.2	18.2	70.2	65.3
16	2.7	2.9	6.2	6.4	19.1	16.5	65.2	59.6
19	2.9	2.9	6.9	6.5	20.5	16.4	61.5	55.2
22	3.4	3.6	7.8	7.8	22.9	18.7	60.8	55.5

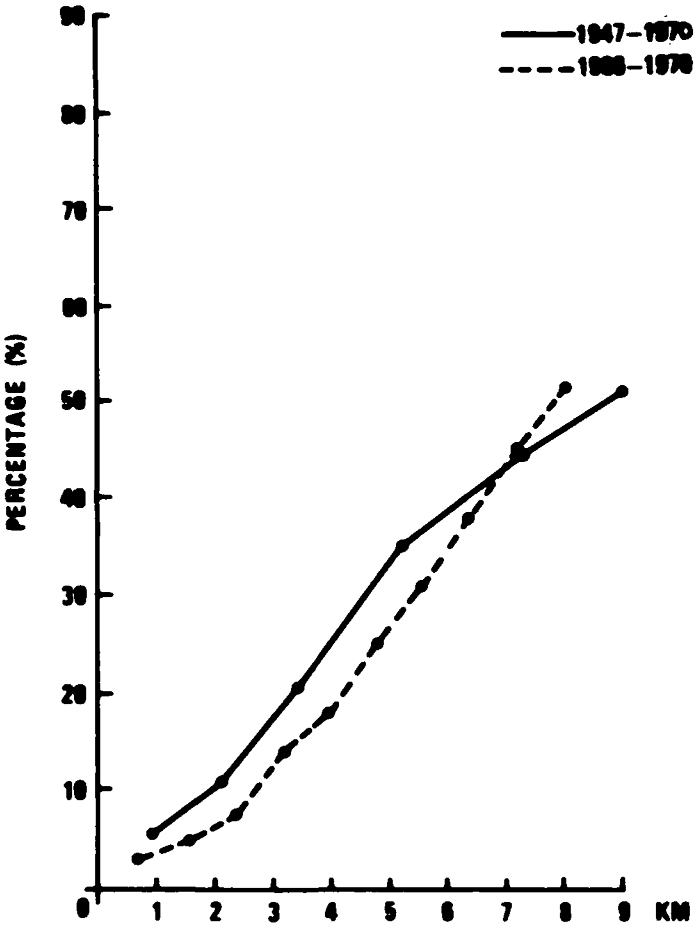
FRANKFURT

PERIOD OF RECORD (A) = 1946-1970; (B) = 1966-1977

HOUR	A	B	A	B	A	B	A	B
1	4.0	2.3	5.1	4.3	27.5	21.0	65.2	57.5
4	5.9	3.6	6.9	5.9	36.3	29.5	74.5	67.2
7	7.4	4.4	8.3	6.6	43.1	38.0	79.0	73.6
10	4.8	3.1	6.2	4.9	32.1	29.5	71.3	64.2
13	2.7	1.6	4.0	3.1	20.9	18.7	64.5	53.5
16	2.6	1.6	3.3	2.7	19.9	17.2	58.4	47.9
19	2.3	1.3	3.3	2.7	20.8	16.7	58.4	49.3
22	3.1	1.6	3.8	3.2	23.4	17.6	61.1	52.6

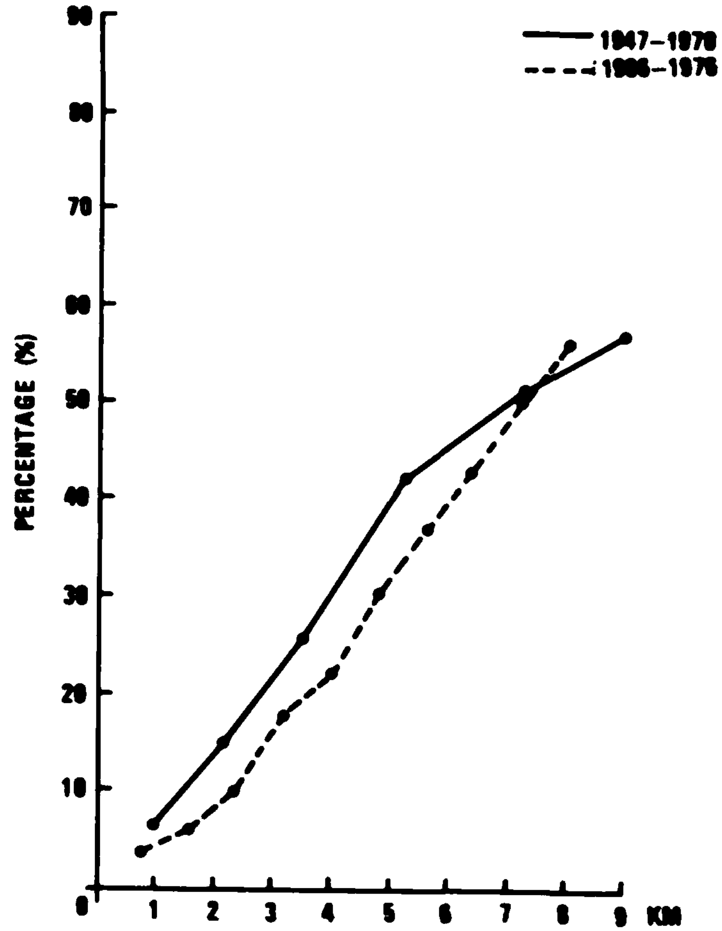
CUMULATIVE DISTRIBUTION OF
VISIBILITY OBSERVATIONS

FRANKFURT HOURS 3–5



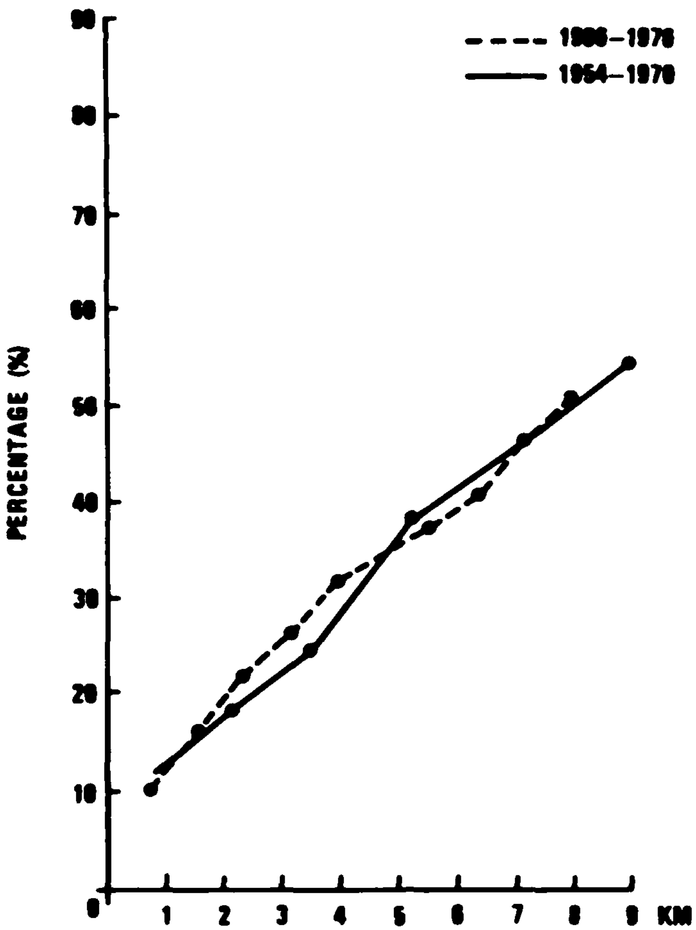
CUMULATIVE DISTRIBUTION OF
VISIBILITY OBSERVATIONS

FRANKFURT HOURS 6–8



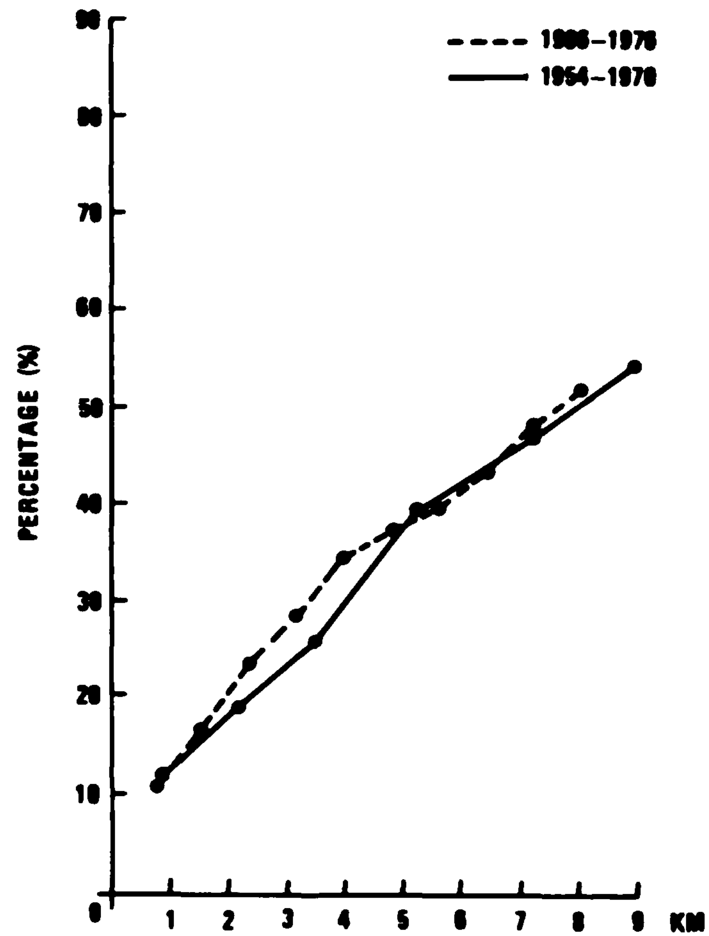
CUMULATIVE DISTRIBUTION OF
VISIBILITY OBSERVATIONS

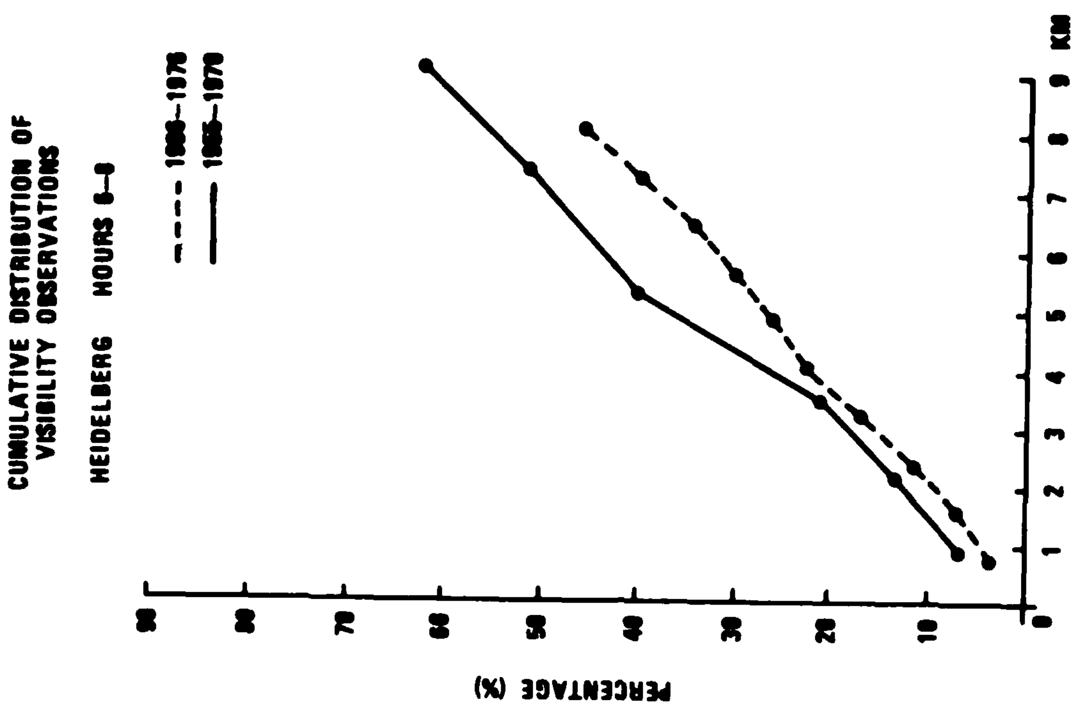
HAHN HOURS 3-5

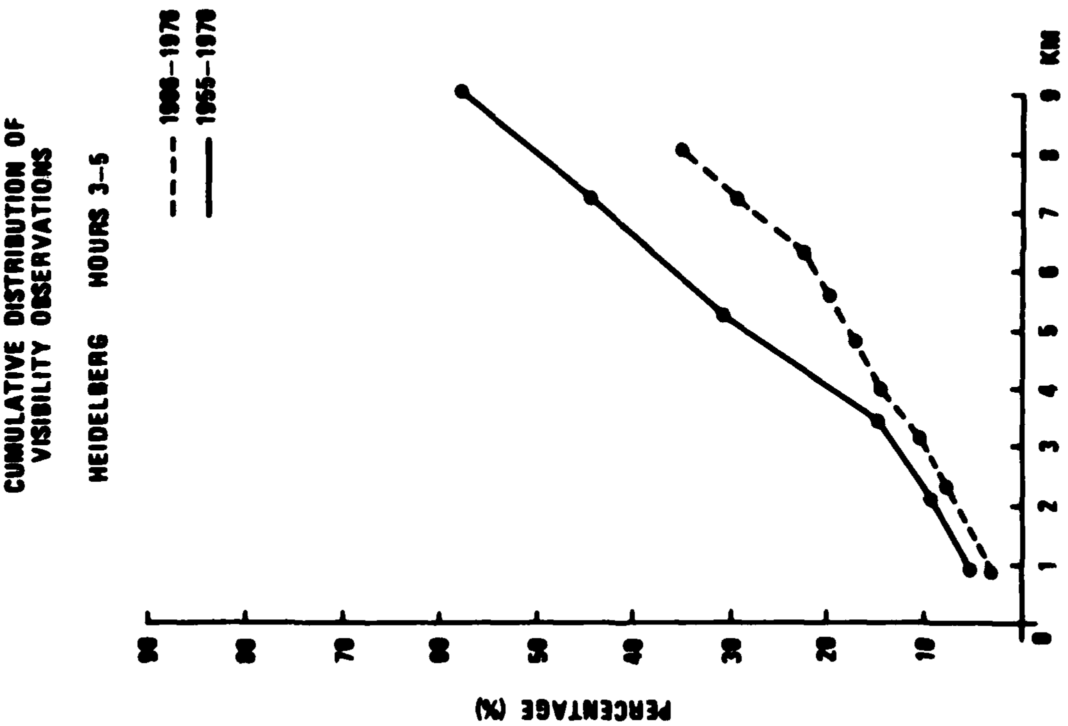


CUMULATIVE DISTRIBUTION OF
VISIBILITY OBSERVATIONS

HAHN HOURS 6-8




CUMULATIVE DISTRIBUTION OF
VISIBILITY OBSERVATIONS
HEIDELBERG HOURS 6–8
PERCENTAGE (%)
70
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
KM


CUMULATIVE DISTRIBUTION OF
VISIBILITY OBSERVATIONS
HEIDELBERG HOURS 3–5
1965–1976
PERCENTAGE (%)
70
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
KM

SINGLE STATION PROBABILITY OF ADVERSE WEATHER

FOR SEP-OCT-NOV IN PERCENT

(LOCAL STANDARD TIME)

1967-1976

HR	V≤1 KM	C≤500 FT	C≤500 FT &/OR V≤ 2 MI	C≤800 FT	C≤800 FT &/OR V≤ 3 MI	C≤2000 FT &/OR V≤ 4 MI	C≤4500 FT &/OR V≤ 4 MI	C≤8000 FT &/OR V≤ 5 MI
1	4.4	5.6	9.3	7.6	16.7	24.5	40.2	57.4
	10.7	18.9	26.3	23.4	34.6	52.1	60.0	73.3
4	6.2	7.6	12.2	9.6	20.4	28.2	46.3	63.0
	13.9	23.7	34.1	29.7	44.0	60.7	68.7	79.6
7	9.2	8.9	20.6	11.7	31.0	42.0	58.9	74.0
	19.2	27.4	38.5	34.4	54.2	72.0	78.9	86.2
10	5.9	6.7	18.6	10.1	30.3	42.8	57.7	69.9
	13.7	23.2	32.3	30.8	48.7	69.8	74.4	83.1
13	2.6	3.6	11.7	5.3	20.3	32.0	49.9	61.7
	6.6	14.2	17.2	20.4	25.3	50.9	59.9	69.2
16	2.2	2.5	9.5	4.0	16.4	25.3	39.8	52.2
	5.6	11.9	14.7	16.8	21.5	37.6	49.6	59.2
19	2.3	3.2	8.2	4.7	15.5	22.8	37.9	54.5
	6.5	12.8	17.0	16.3	24.5	38.4	51.3	62.8
22	3.2	5.2	8.8	6.4	15.0	23.3	37.4	55.3
	8.2	14.2	19.6	17.5	27.0	42.2	54.3	67.9

SINGLE STATION PROBABILITY OF ADVERSE WEATHER

FOR DEC-JAN-FEB IN PERCENT

(LOCAL STANDARD TIME)

1967-1976

HR	V≤1 KM	C≤500 FT	C≤500 FT &/OR V≤ 2 MI	C≤800 FT	C≤800 FT &/OR V≤ 3 MI	C≤2000 FT &/OR V≤ 4 MI	C≤4500 FT &/OR V≤ 4 MI	C≤8000 FT &/OR V≤ 5 MI
1	2.9	5.6	14.2	10.0	25.1	39.8	60.1	72.6
	18.7	32.2	42.0	39.7	53.4	70.0	77.9	84.4
4	3.4	7.4	15.2	10.8	24.9	41.2	62.2	75.6
	20.4	34.8	44.0	43.3	56.3	73.1	80.8	87.1
7	4.6	7.7	16.7	11.9	26.6	43.4	66.4	78.9
	21.9	35.8	46.3	45.1	58.3	75.7	83.1	87.2
10	6.0	7.0	24.0	12.8	37.8	52.0	68.9	82.1
	23.6	35.6	48.2	43.7	59.6	77.7	82.3	89.9
13	4.1	4.8	19.9	9.2	31.9	48.3	66.3	78.4
	17.2	30.2	40.9	37.9	49.9	73.1	78.1	86.8
16	3.8	4.3	17.0	6.4	28.2	41.9	61.8	74.9
	16.2	27.2	36.7	34.0	46.1	65.2	73.2	78.9
19	2.2	3.8	14.6	7.1	24.8	39.6	59.8	73.2
	14.4	27.4	36.9	35.3	48.0	65.4	73.6	82.3
22	2.6	4.9	14.4	9.0	24.6	38.4	59.3	72.3
	16.6	29.8	38.8	37.1	50.0	67.3	75.0	83.0

SINGLE STATION PROBABILITY OF ADVERSE WEATHER

FOR NOVEMBER IN PERCENT

(LOCAL STANDARD TIME)

1967-1976

HR	V≤1 KM	C≤500 FT	C≤500 FT &/OR V≤ 2 MI	C≤800 FT	C≤800 FT &/OR V≤ 3 MI	C≤2000 FT &/OR V≤ 4 MI	C≤4500 FT &/OR V≤ 4 MI	C≤8000 FT &/OR V≤ 5 MI
1	6.7	9.3	12.3	12.7	21.7	32.7	55.7	70.3
	13.3	26.0	33.7	31.7	41.7	58.3	71.3	81.7
4	6.3	9.7	14.3	12.0	22.0	31.7	58.0	71.0
	18.3	31.0	40.3	39.0	51.7	64.0	78.7	86.3
7	6.3	9.7	14.3	13.7	26.3	38.0	63.7	79.0
	18.0	33.3	41.7	44.0	55.0	71.0	82.3	89.3
10	6.0	7.7	22.3	12.7	33.7	48.7	67.3	77.7
	20.3	30.0	40.7	39.7	54.7	76.3	81.7	88.3
13	5.0	5.3	16.0	8.3	28.0	43.0	63.0	75.0
	11.7	22.7	26.7	33.0	38.0	65.3	73.0	82.3
16	4.3	4.3	14.7	6.0	25.0	38.3	58.7	73.7
	10.7	19.7	24.3	29.0	35.3	54.3	66.0	69.7
19	4.3	5.3	11.3	8.3	21.3	32.0	53.7	67.7
	11.3	20.0	25.7	25.3	35.0	53.7	68.7	76.0
22	4.3	8.3	12.0	12.0	23.0	35.3	56.7	71.0
	15.3	22.7	30.7	27.3	38.3	52.3	70.3	79.7

SINGLE STATION PROBABILITY OF ADVERSE WEATHER

FOR SEP-OCT-NOV IN PERCENT

(Local Standard Time)

1961-1970 (Except SEP-NOV 67)

HR	V≤1 KM	C≤500 FT	C≤500 FT &/OR V≤ 2 MI	C≤800 FT	C≤800 FT &/OR V≤ 3 MI	C≤2000 FT &/OR V≤ 4 MI	C≤4500 FT &/OR V≤ 4 MI	C≤8000 FT &/OR V≤ 5 MI
1	3.7	4.3	12.5	5.7	18.2	33.8	41.8	54.6
	12.1	22.2	29.7	28.5	44.2	56.9	65.0	71.2
4	4.8	5.0	14.4	6.8	21.1	37.7	47.0	60.8
	16.4	27.0	35.5	33.5	52.6	66.5	72.4	77.1
7	7.3	6.5	23.3	8.2	30.8	47.0	55.1	67.8
	20.2	30.5	39.9	37.2	58.4	74.0	82.5	86.6
10	4.5	5.4	19.1	6.4	26.7	45.6	50.4	63.1
	15.4	25.9	33.6	34.1	52.1	71.2	80.7	84.4
13	2.1	2.9	11.7	3.8	17.0	33.9	42.0	52.6
	6.9	19.1	21.7	23.7	32.2	50.4	64.6	71.8
16	2.1	1.3	8.3	2.4	13.6	26.6	33.5	44.7
	6.7	15.8	18.8	19.7	27.1	40.9	53.2	59.7
19	1.8	1.3	8.7	2.0	14.7	29.1	37.4	51.9
	7.6	15.6	22.5	19.5	34.1	48.2	57.9	65.1
22	1.7	1.6	9.4	2.3	15.5	29.3	37.9	51.2
	9.2	19.1	24.5	23.8	38.0	50.7	58.9	66.3

SINGLE STATION PROBABILITY OF ADVERSE WEATHER

FOR DEC-JAN-FEB IN PERCENT

(Local Standard Time)

1961-1970 (Except DEC 67-FEB 68)

HR	V≤1 KM	C≤500 FT	C≤500 FT &/OR V≤ 2 MI	C≤800 FT	C≤800 FT &/OR V≤ 3 MI	C≤2000 FT &/OR V≤ 4 MI	C≤4500 FT &/OR V≤ 4 MI	C≤8000 FT &/OR V≤ 5 MI
1	3.0 16.9	4.9 35.6	16.1 41.6	8.0 44.6	26.7 58.5	44.0 75.6	55.6 81.6	66.9 86.2
4	2.7 18.9	5.2 39.1	18.3 46.1	9.0 47.2	26.7 63.6	47.9 78.6	57.4 83.8	67.7 87.8
7	3.3 17.2	5.3 38.3	18.2 47.4	9.9 49.1	28.3 65.9	49.8 83.1	58.2 87.8	69.6 91.0
10	4.9 22.1	5.7 38.0	26.1 49.4	8.6 46.5	38.3 65.8	58.8 79.6	64.7 86.7	73.2 90.6
13	3.6 16.4	5.4 35.1	23.2 42.7	7.4 43.6	34.0 57.8	49.8 75.2	56.3 82.2	66.7 86.8
16	4.1 16.5	4.9 31.6	22.0 40.0	7.4 40.1	29.9 56.5	46.1 73.1	53.5 80.4	62.7 84.4
19	2.0 13.7	4.9 30.1	17.8 38.5	6.9 40.1	28.2 58.9	45.7 74.2	55.7 81.6	68.3 85.7
22	2.2 12.8	3.5 33.0	15.4 39.1	5.6 40.9	25.7 56.5	42.1 73.3	52.0 79.8	62.5 84.8

SINGLE STATION PROBABILITY OF ADVERSE WEATHER

FOR NOVEMBER IN PERCENT

(Local Standard Time)

1961-1970 (Except NOV 67)

HR	V≤1 KM	C≤500 FT	C≤500 FT &/OR V≤ 2 MI	C≤800 FT	C≤800 FT &/OR V≤ 3 MI	C≤2000 FT &/OR V≤ 4 MI	C≤4500 FT &/OR V≤ 4 MI	C≤8000 FT &/OR V≤ 5 MI
1	3.3	5.9	12.2	6.3	18.9	34.4	44.4	56.3
	17.0	34.8	42.6	43.7	57.4	71.9	78.9	84.4
4	3.3	5.6	13.0	6.7	18.9	34.1	45.6	58.9
	21.5	36.7	44.4	45.2	61.9	77.8	83.7	87.8
7	4.4	6.7	14.1	8.5	22.2	38.9	52.2	64.8
	20.7	39.6	45.2	47.8	60.4	77.8	83.7	87.8
10	4.8	6.7	19.6	8.2	26.3	48.5	55.2	67.4
	23.0	36.7	46.3	47.4	61.1	80.7	88.9	91.9
13	3.3	5.2	12.6	7.4	19.6	39.6	46.7	56.7
	13.0	34.1	38.5	40.4	49.6	68.2	81.5	85.2
16	3.0	2.6	11.5	5.2	19.6	34.1	43.7	55.6
	13.0	27.4	33.0	34.8	44.8	64.1	75.6	80.7
19	2.6	3.0	8.5	4.1	16.7	33.0	44.8	58.2
	13.0	27.4	35.2	34.4	48.9	66.7	76.3	82.2
22	2.2	1.9	10.4	4.1	18.2	35.6	45.2	55.2
	15.2	33.0	38.9	40.0	51.9	67.8	76.3	80.4

VISIBILITY $\leq$ 1 KM (PROBABILITIES)

FALL

HOUR	HEID	FRANK	SAAR	HAHN
1	5.3%	4.4%	8.2%	10.7%
4	6.2	7.9	12.0	13.8
7	9.2	10.0	16.9	19.3
10	5.9	6.9	12.4	13.7
13	2.6	3.1	4.3	6.6
16	2.6	2.4	2.2	5.6
19	2.9	2.3	3.8	6.5
22	4.2	3.2	4.1	8.1

HEIDELBERG
FRANKFURT
SAARBRUECKEN
HAHN

SINGLE STATION PROBABILITY

FALL

HOUR	HEID		FRANK		SAAR		HAHN	
1	57.4%	46.9	67.2%	43.3	73.3%	42.2	65.0%	51.5
4	63.0	50.8	74.7	48.9	79.6	49.1	71.5	55.7
7	74.0	56.8	83.2	54.0	85.2	53.4	74.7	61.1
10	69.9	52.3	79.4	53.6	83.6	55.2	71.3	59.4
13	64.1	49.8	61.6	46.5	69.2	53.7	63.8	57.8
16	59.2	47.5	52.2	39.6	58.5	46.6	56.4	49.5
19	54.5	45.2	57.3	41.8	62.8	42.3	60.1	48.6
22	55.3	47.0	61.3	43.0	67.9	42.9	59.6	48.2

HEIDELBERG
FRANKFURT
SAARBRUECKEN
HAHN

FIRST COLUMN: $C < 8000$ FT AND/OR $V \leq 5$ MI
SECOND COLUMN: $C < 8000$ FT

JOINT PROBABILITIES (%)
BETWEEN TWO STATIONS
FALL

HOUR	SA-HA		HEI-FR		HEI-HA		FR-HA		HEI-SA		SA-FR	
1	56	36%	48	33%	49	37%	52	34%	50	32%	57	30 %
4	63	41	55	37	54	40	59	39	57	37	65	34
7	69	45	66	42	62	45	66	43	69	42	74	40
10	67	46	62	40	57	41	62	42	65	40	71	40
13	53	43	49	34	50	41	47	38	54	37	51	37
16	44	35	42	29	43	35	39	31	46	34	41	29
19	49	34	42	31	42	32	45	33	46	32	46	30
22	51	34	43	33	44	34	47	34	47	33	50	31

FIRST COLUMN: C < 8000 FT AND/OR V $\leq$ 5 MI

SECOND COLUMN: C < 8000 FT

CORRELATION COEFFICIENT

CONTINGENCY TABLE

a	b	R_1
c	d	R_2
S_1	S_2	T

$$r^2 = \left(\frac{(ad - bc)^2}{R_1 R_2 S_1 S_2}\right)$$

$r = 0$ for $a = R_1 S_1$.

α = 95% LEVEL OF SIGNIFICANCE.

H: $r \neq 0$: $r \geq$ 0.055 (ONE SIDED)

0.067 (TWO SIDED)

THREE SIGMA

$r \geq$ 0.10 (ONE SIDED)

0.11 (TWO SIDED)

TWO STATION CORRELATIONS

VISIBILITY $\leq$ 1 KM

FALL

HOUR	40 SA-HA	50 HEI-FR	70 HEI-HA	70 FR-HA	80 HEI-SA	90 SA-FR
1	.34	.57	<u>.19</u>	<u>.15</u>	.31	.33
4	.34	.43	.16	.11	.26	.24
7	.29	.36	.18	.14	<u>.37</u>	<u>.35</u>
10	.28	.39	.16	.12	.27	.29
13	.21	.33	.10	.06	.13	.18
16	.32	.42	.05	.12	.12	.17
19	<u>.46</u>	.59	.12	.11	.10	.20
22	.39	<u>.62</u>	.10	.13	.18	.25

* (MAXIMUM UNDERLINED)

MEAN AREAL CORRELATION

FALL

GROUP	40 SA-HA	50 HEI-FR	70 HEI-HA	70 FR-HA	80 HEI-SA	90 SA-FR
C < 500 FT	.38	.42	.10	.17	.18	.26
C < 800 FT	.42	.45	.13	.18	.20	.26
C < 2000 FT	.49	.47	.23	.29	.27	.34
C < 4500 FT	.52	.44	.40	.42	.42	.42
C < 8000 FT	.53	.49	.46	.47	.48	.45
C < 2000 FT &/OR V < 4 MI	.43	.48	.31	.27	.40	.38
C < 8000 FT &/OR V < 5 MI	.46	.41	.41	.35	.42	.36

(HOURS OF DAY AVERAGED)

THREE STATION MEAN CORRELATION

	FRANKFURT-HEIDELBERG (50 MILES)		HAHN-SAARBRUECKEN (40 MILES)	
	HAHN (60 MI)	SAAR (80 MI)	HEID (70 MI)	FRANK (80 MI)
V < 1 KM	.07	.19	.15	.16
C < 500 FT	.08	.17	.13	.25
C < 800 FT	.11	.18	.17	.23
C < 2000 FT	.20	.25	.26	.34
C < 4500 FT	.36	.39	.44	.44
C < 8000 FT	.44	.46	.46	.46
2000/4 MI	.27	.36	.38	.33
8000/5 MI	.39	.39	.44	.37

(HOURS OF DAY AVERAGED)

THREE STATION CORRELATION

FALL

FRANKFURT - SAARBRUECKEN (90 MILES)

	HEID (40 MI-SE)		HAHN (25 MI-NE)		CLOSE STATIONS	
	MEAN	MAX	MEAN	MAX	MEAN (HIGH)	MAX
V < 1 KM	.29	.44	.16	.22	.19	.29
C < 500 FT	.27	.43	.23	.31	.25	.37
C < 800 FT	.33	.39	.24	.30	.23	.32
C < 2000 FT	.40	.47	.35	.41	.34	.42
C < 4500 FT	.44	.49	.46	.52	.44	.52
C < 8000 FT	.47	.50	.48	.52	.46	.54
2000/4 MI	.48	.60	.34	.44	.38	.51
8000/5 MI	.43	.48	.40	.49	.44	.49

(MEAN = AVERAGE OF HOURS OF DAY)

FOUR STATION AREA CORRELATION
FALL

(THREE STATIONS PLUS ONE INDIVIDUAL)

	HEIDEL	FRANK	HAHN	SAARB
$V \leq 1$ KM	.20	.23	.12	.21
$C < 500$	.19	.23	.12	.18
$C < 800$	.25	.28	.14	.20
$C < 2000$	.36	.38	.24	.28
$C < 4500$	.42	.42	.38	.42
$C < 8000$	.44	.46	.44	.46
2000/4 MI	.45	.40	.29	.35
8000/5 MI	.42	.36	.41	.38

(LISTED STATION IS THE SINGLE STATION)

(AVERAGED HOURS OF DAY)

FOUR STATION CORRELATION

FALL

(TWO STATION EVALUATION)

	HA/SA-FR/HEI W - E	FR/HA-SA/HEI N - S	SA/FR-HA/HEI CROSSOVER	THREE + 1 HIGH MEAN
V ≤ 1 KM	.12	.32	.29	.23
C < 500 FT	.12	.28	.29	.23
C < 800 FT	.14	.32	.32	.28
C < 2000 FT	.25	.43	.43	.38
C < 4500 FT	.42	.48	.49	.42
C < 8000 FT	.50	.50	.52	.46
2000/4 MI	.34	.46	.47	.45
8000/5 MI	.43	.44	.43	.42

(TWO STATIONS VERSUS TWO STATIONS)

FOUR STATIONS, FALL

AREA PERSISTENCE (MEAN CORRELATION)

HOUR	$V \leq 1$ KM	$C < 500$ FT	$C < 8000$ FT	$C < 8000$ FT/$V \leq 5$ MI
1	.26	.28	.50	.41
4	.22	.23	.45	.35
7	.17	.16	.46	.32
10	.11	.10	.45	.34
13	.14	.07	.40	.38
16	.17	.17	.41	.43
19	.20	.20	.45	.44
22	.26	.23	.50	.42

(CORRELATIONS OF FOUR COMBINATIONS "THREE-STATION VERSUS ONE STATION" AVERAGED)

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A DISCUSSION OF THE SYNTHETIC IR CLOUD SCENES OF PHOTON RESEARCH ASSOCIATES

Edward J. Stone
Naval Research Laboratory

A Discussion of the Synthetic IR Cloud Scenes of Photon Research Associates

Edward J. Stone
Code 6520, Naval Research Laboratory, Washington DC 20375

ABSTRACT

(U) The Photon Research Associates cloud reference data scenes consist of 12 synthetic images of high and low cloud, in four different infrared wavelength bands with different sun conditions, as seen by a space observer. Several of these are displayed and examined in the light of present understanding of cloud radiance. Specific questions considered include:

- Absolute values of apparent cloud radiance, and distribution of radiance values
- Edge radiance profiles, partially cloud-filled pixels, and the apparent distribution of optical thickness
- Scale and sharpness of internal cloud structure

Examples of measured infrared cloud images from the Daedalus and Landsat Thematic Mapper instruments are displayed and compared to the synthetic scenes.

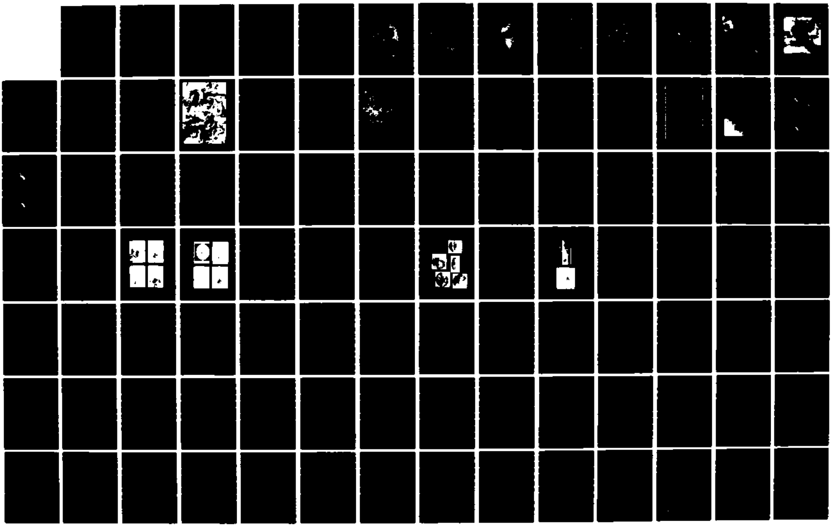
INTRODUCTION

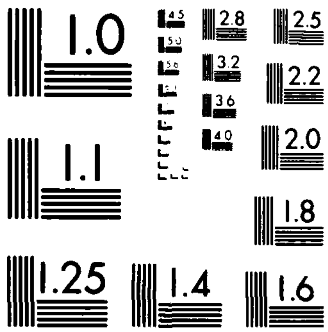
One of the most obvious and pressing needs in development of infrared air vehicle detection techniques is the acquisition of a sufficient data set for performing the necessary simulations. For clouds in the downlooking case, a few sets of data have been acquired. The most important sensors are Landsat-D, Daedalus, and Hi-Camp. They have provided a good deal to work with, but for the purposes of development of advanced sensors, they often have inadequacies, such as small dynamic range, low sensitivity, and poor spatial resolution.

In addition to these problems, which can be overcome, there is an inherent difficulty: images acquired from high altitude sensors fail to give the three dimensional structure of the clouds viewed. To obtain a three-dimensional structure one must make assumptions about the optical thickness and microphysics of the cloud in each pixel and the general structure of the cloud. Without a three-dimensional reconstruction of the scene, it is impossible to do simulations with the scene at different aspect or illumination geometries or to include the effect of parallax due to cloud motion and sensor motion.

AD-A152 735 PRESENTATIONS AT THE TRI-SERVICE CLOUD MODELING WORKSHOP (2ND) HELD AT TH..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA E BAUER AUG 84 IDA-M-9-VOL-1 6/7

UNCLASSIFIED IDA/HQ-84-28971 MDA903-84-C-0031 F/G 4/2 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

This problem can be overcome by beginning with a three-dimensional structure for a scene and then calculating the radiance values from first principles. The resulting scene is synthetic, but it is more amenable to simulations. The disadvantages, of course, are that the scene is only "real" to the extent that the synthesized forms are similar to those in nature, that one's knowledge of optics is complete and that one is able to perform the detailed radiative transfer calculation thoroughly.

Some of the requirements which a synthetic scene must meet are:

- Spatial resolution at least as great as that of the sensor whose performance is to be modeled. A spatial (angular) resolution the same as that of the sensor permits direct simulations against background for that static scene only, such as a flythrough viewed by a staring earth-synchronous satellite. To adequately model the effects of spatial changes of various sorts, such as jitter, a moving sensor platform, or motion of the background features, however, one should have a modeled scene at substantially higher resolution than that of the sensor being modeled.

- Adequate sensitivity, that is, having a high resolution in radiance. Precision itself is rarely a problem, since quantities are usually calculated with much more precision than they can be measured. The requirement is for the physical quantities in a scene to vary from pixel to pixel in a realistic way, to include both gradual and precipitous variation. For example, an entire cloud or terrain region cannot be characterized by a single temperature. (A related problem in modeling is the inclusion of the right amount and kind of noise on the data.)

- Three-dimensional structure. The simulator needs to be able to model the effects of in-scene motion and sensor motion.

- 'Realistic' forms. The true requirement here is that the modelled scene with implanted target respond to various signal processing schemes with the same number of false alarms, and true and missed detections, as the real scene would. In principle there is no requirement that the scene 'look' realistic. However, there is no practical basis for comparison other than the natural forms.

P.R.A. SYNTHETIC SCENES OF IR CLOUDS

Photon Research Associates, Inc., of La Jolla, California have been commissioned by DARPA to generate infrared images of the Earth and atmosphere from space, which may be used for simulations of military satellite-based surveillance. A large set of scenes, known collectively as the Reference Scene Data Base, has been generated, which includes scenes of mountains, coastlines, urban areas, tundra, and clouds.

These scenes are based on a detailed pixelized specification of an area, including orography, spectral reflectance and emittance, thermal conductivity, and so forth for each pixel in the image. A computer program then generates an optical image based on some choice of wavelength band, sun position, time of day, model atmosphere, and viewing geometry.

The clouds scenes shown here were generated by starting with a photographic image and generating from it a three-dimensional structure for the cloud. This was done by fitting geometrical ellipsoidal forms to the photographic image. "Texture", meaning a random variation in altitude of the viewed surface on a scale smaller than the scale of the ellipsoid, was then applied to the cloud form using a correlated Gaussian method. The cloud forms were then cut off below a certain altitude, to simulate the condensation level, leaving thin places and "islands" in the cloud. A radiance calculation was performed which included light reflected by the cloud from the sun, light transmitted through the cloud, light emitted thermally by the cloud, and the path radiance and transmittance of the atmosphere.

Two physical cloud scenes were generated, one to represent low-altitude cumulus ("Low cloud"), and one to represent a cumulonimbus (thunderhead) with a large range of cloud altitudes in view ("High Cloud"). The calculation was performed in several different wavebands and for different sun positions to generate 12 scenes in all. The images are 512 x 512 pixels, and are available from PRA on computer-compatible tapes.

FIGURES

The figures presented in this 'hardcopy' are substitutes for color image transparencies used in the oral presentation.

Figure 1 (A and B). High Cloud over Ocean, Middle Infrared

Photon Research Associates scene of high cloud over ocean in the middle infrared, shown as a coarsely-sampled 3-D plot (A) and as a contour plot (B). In the 3-D plot, 'up' is colder, 'down' is warmer, so that the radiance plot is similar to the physical geometry of the cloud. This is a 64x64 representation of the original 512x512 image.

The histogram shows the number of pixels with given radiant intensity, intensity increasing left to right (cold to warm). The spike in the histogram at the extreme right is the radiance of the ocean background. The gap in the histogram between the ocean and cloud radiance indicates that no pixels in the scene were considered to be partially cloud-filled, nor did any parts of the cloud have very low optical thickness.

The image is intended to be an example of cumulonimbus (thunderhead). It displays a wide range of radiances, and thus altitudes, and might represent the early congestus stage of such a storm. No capillatus or cirrus anvil appears to be present, nor associated cumulus or stratus formations.

Figure 2. (A and B). Low Clouds over Ocean, Middle Infrared

PRA scene of low cloud over ocean, shown in the middle IR with a low sun, shown as both 3-D plot (A) and contour plot (B). Again, 'up' is cold, and 'down' is warm. Both hard and soft edges are apparent, and the histogram of intensity shows some intensities approaching those of the warm ocean. These two plots are 64x64 arrays, coarsely sampled from the original 512x512 image.

Figure 3. Detail: High Cloud over Ocean, Long-wave Infrared

Enlargement of portion of Photon Research Associates scene of high cloud over ocean. All of the edges appear hard, indicating no partially filled pixels and no thicknesses approaching zero. This is a 64x64 section of the original 512x512 digital image.

Figure 4. Detail: Low Cloud over Ocean, Middle Infrared

Enlargement of part of the Photon Research Associates synthetic scene of low cloud over ocean in the middle IR. Most of the edges show gradual variation to the radiance level of the ocean. There are few structures smaller than about 100 meters. At this altitude, smaller features are expected.

Figure 5. Detail: High Cloud, Long-wave Infrared

Enlargement of portion of PRA Scene of high cloud in the middle IR. Note the filamentary structures, with dimensions as small as 1 pixel across, which are synthetic. While these features do not appear to be "realistic", they may nonetheless be suited for simulations as generators of false alarms.

Figure 6. Detail: Daedalus Image of Cloud over Sierra Nevada

This portion of a Daedalus long-wave (10-12 microns) image of patchy cloud over the Sierra mountains shows small features with a characteristic dimension of 2 or 3 pixels. Some of these features appear to be filament-like in the displayed image. This should be compared to the synthetic texture in the previous figure. The projected pixel sizes are approximately the same.

Table: Rough estimates of scale of texture as a function of altitude.

These estimates are based on the assumption that the condensed water in a volume of cloud is equal to the water vapor content (it is usually less). It assumes an average cloud droplet radius of 10 microns. The actual droplet size distribution in a cloud depends on many things, including cloud age, altitude, and concentration of aerosol condensation nuclei. In general, the smaller the droplets, the more opaque the cloud.

It is possible at any altitude to have diffuse, unstructured formations with extents of may kilometers; it is also possible to have short distances corresponding to significant optical depths, for example, by viewing a thin feature edge-on. These numbers therefore serve only as a guide. But a scene of cloud at a given altitude would be be likely to have features in some distribution about the dimensions indicated.

REFERENCE

1. Photon Research Associates, La Jolla, CA, Two-Dimensional Data Assessment and Applications Study. Final Report (U), Volume I: Reference Scene Data Base (August 1983), Report R-058-83, SECRET

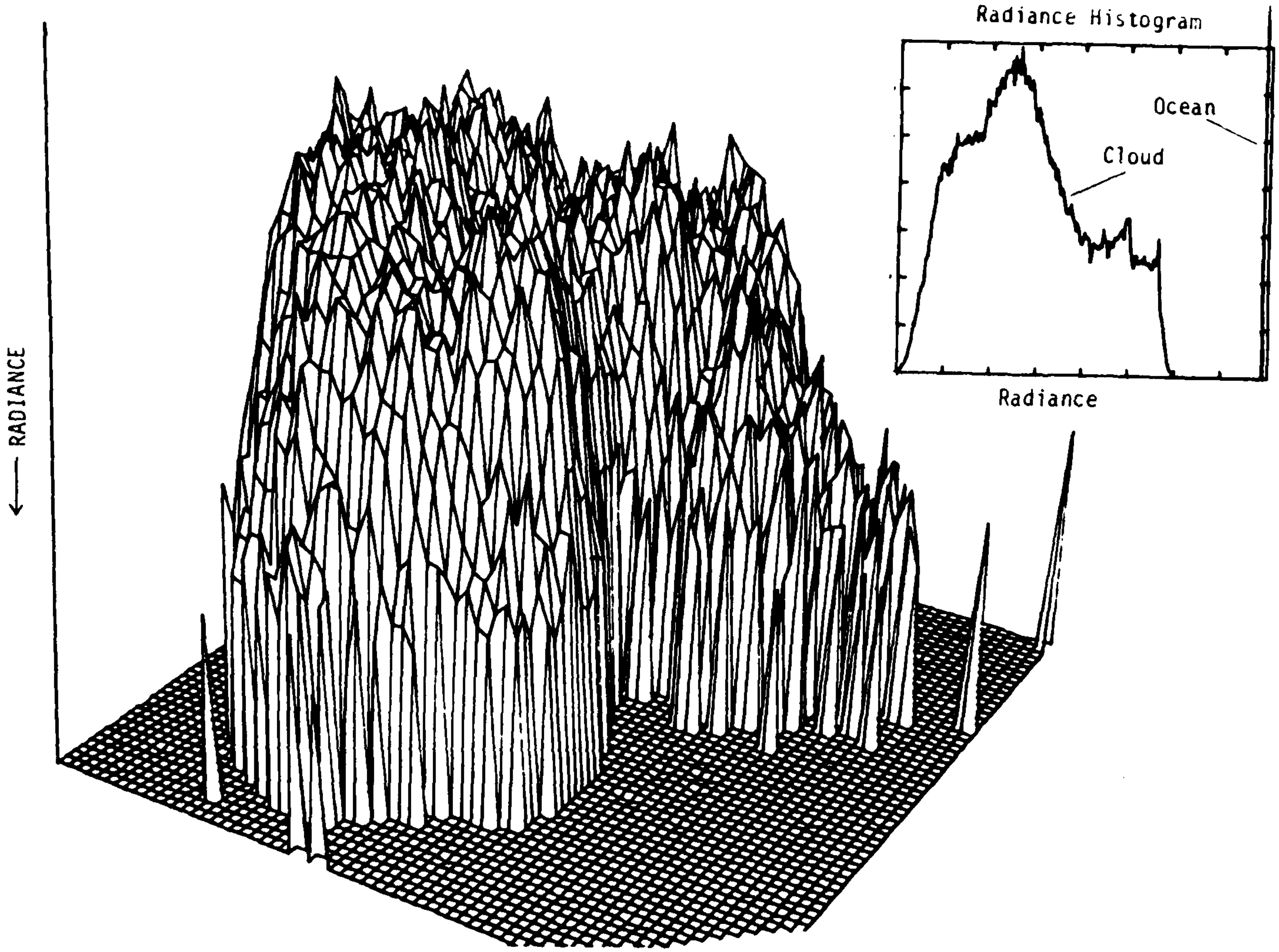


Figure 1A. PRA synthetic scene of high cloud in the middle IR, and histogram of the radiance distribution.

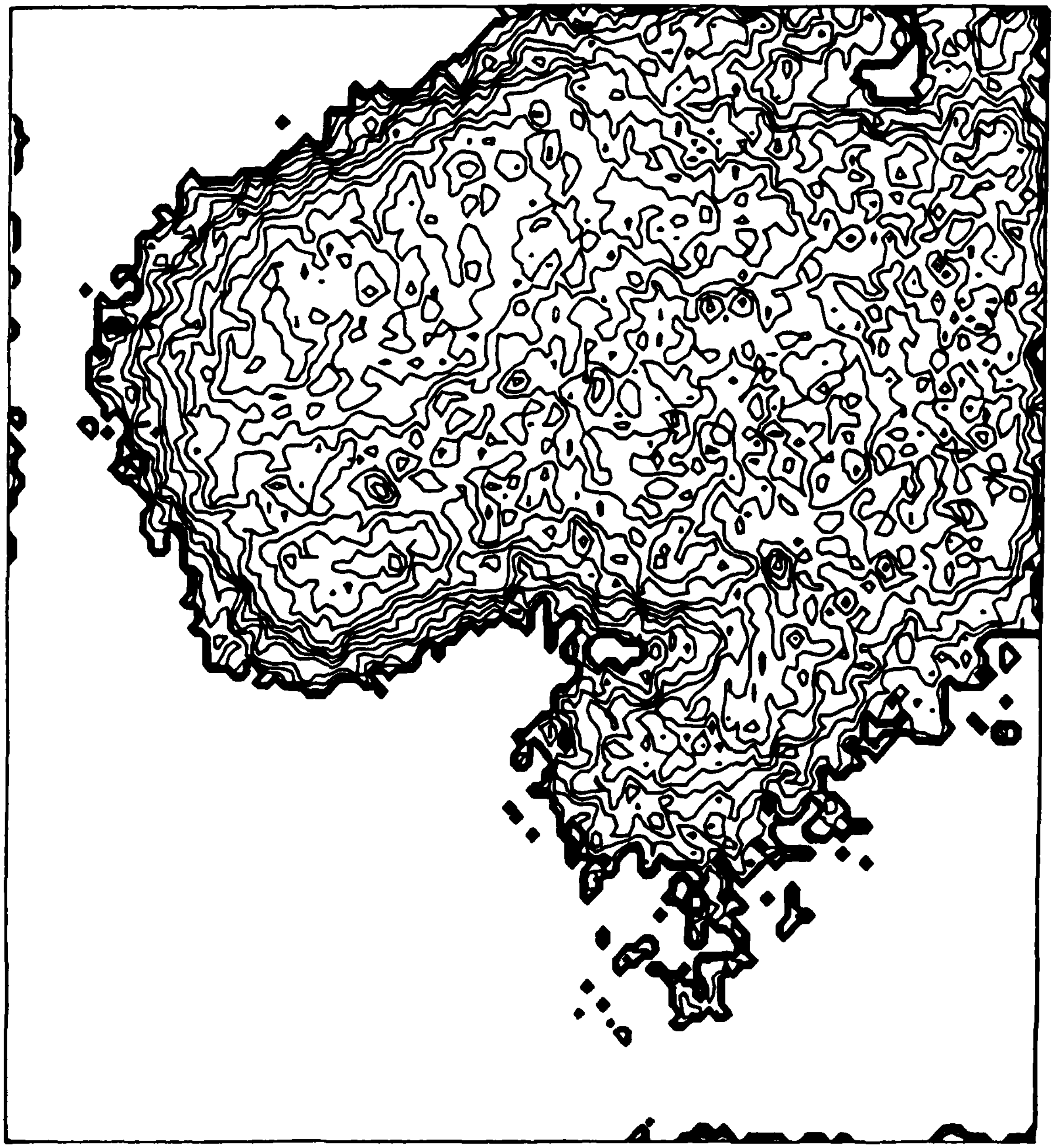


Figure 1B. Contour plot of the scene of Figure 1A.

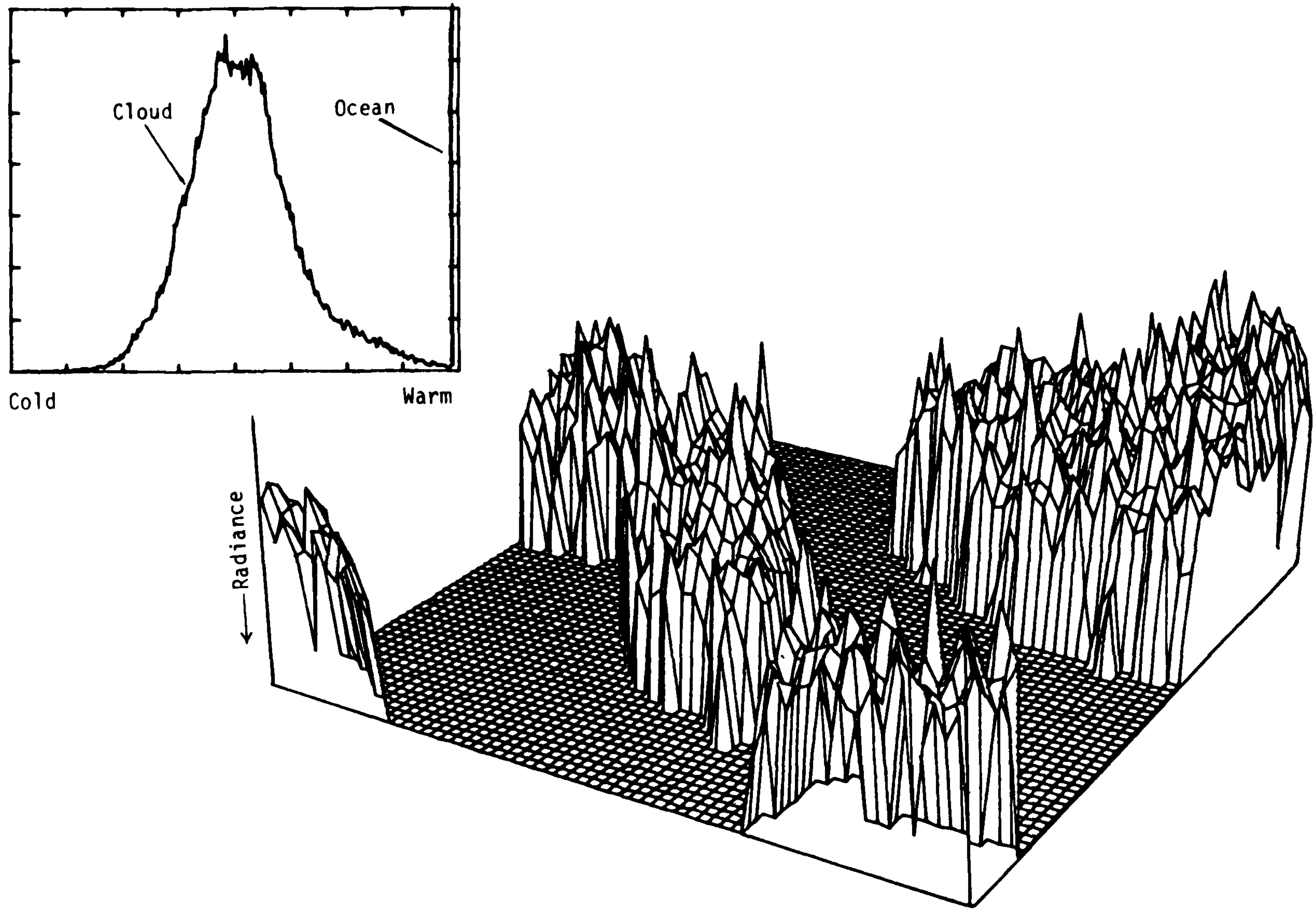


Figure 2A. PRA synthetic scene of low cloud in the middle IR, and histogram of the radiance distribution.

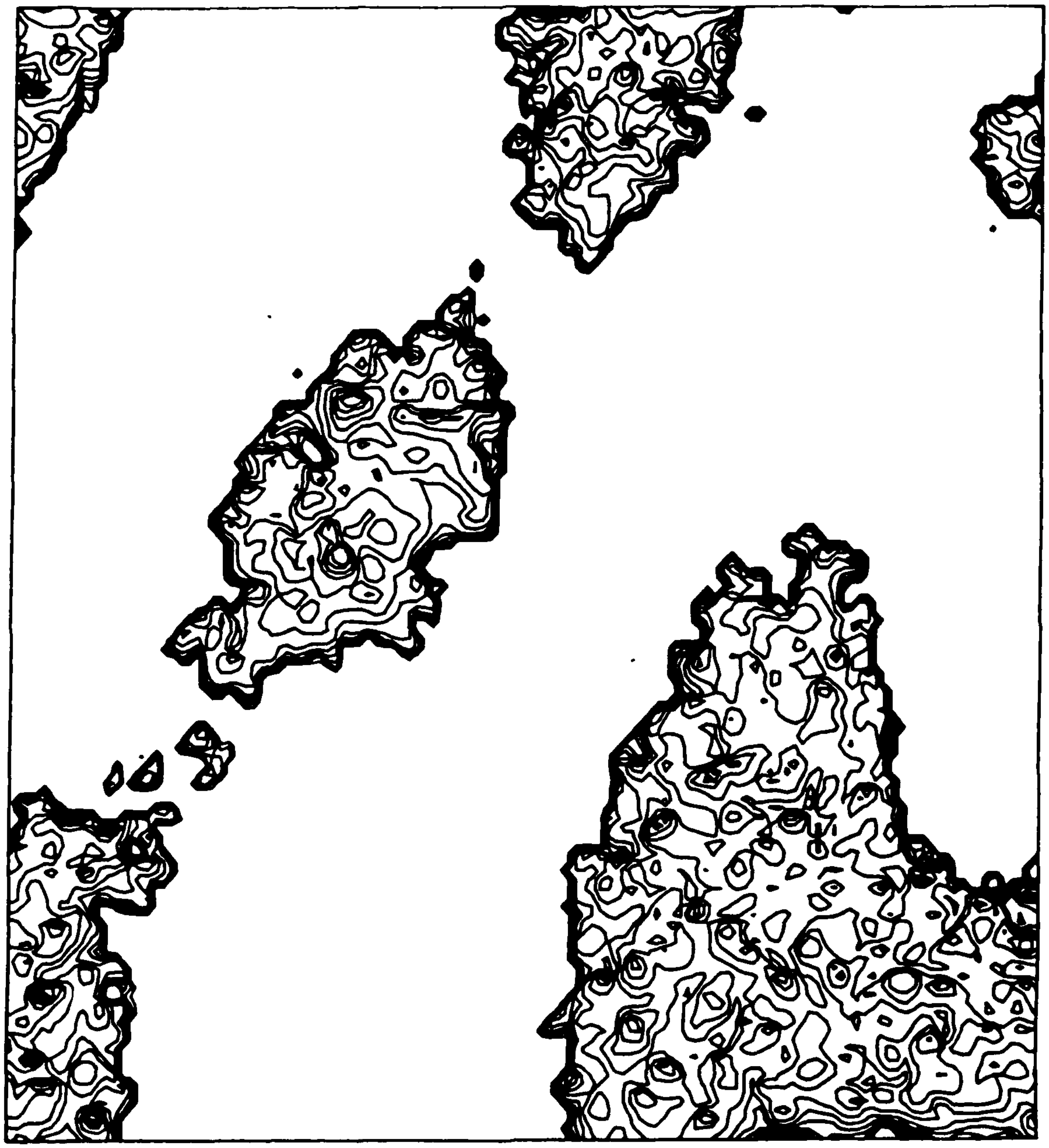


Figure 2B. Contour plot of the low cloud, mid-IR scene of Figure 2A.

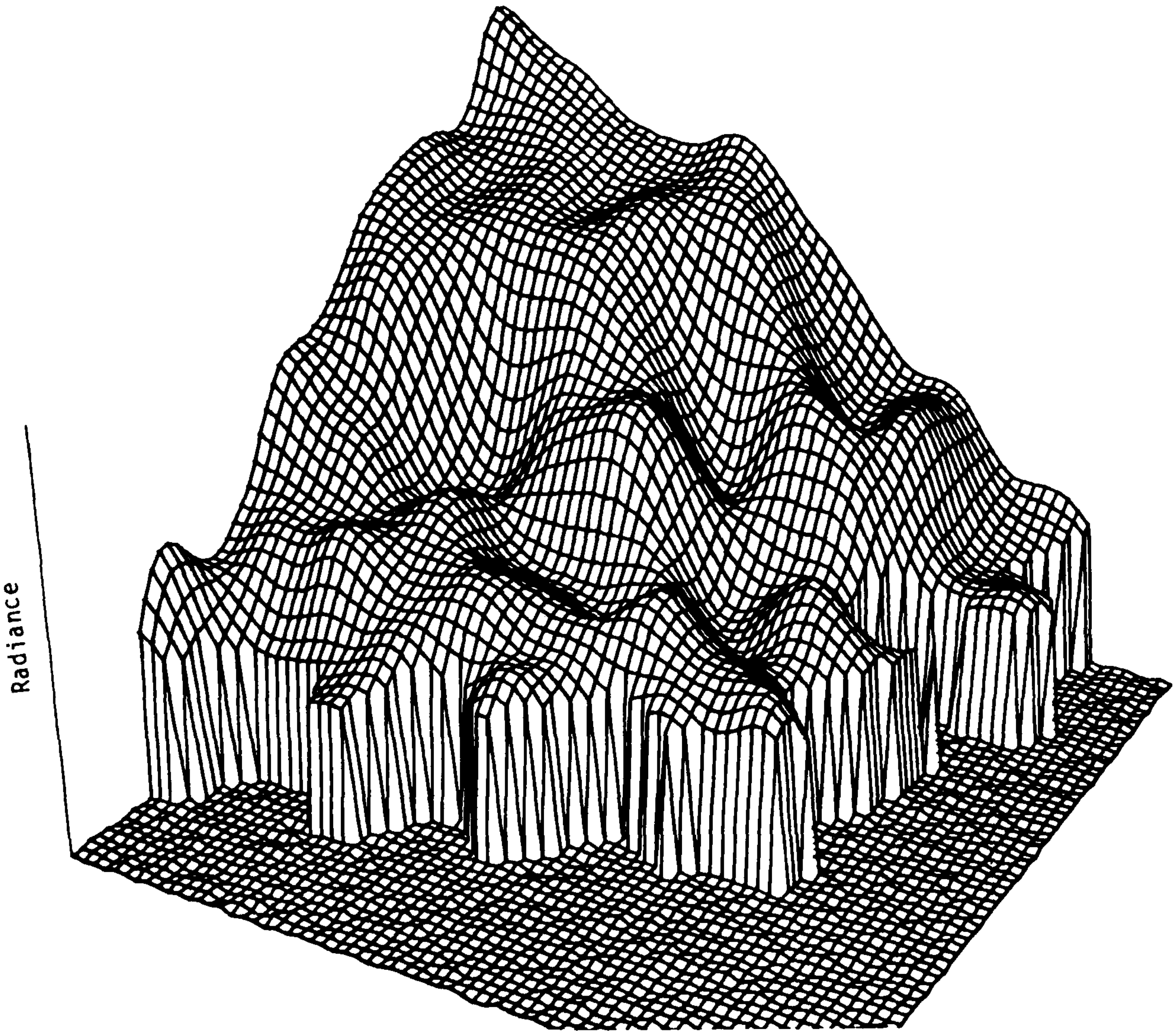


Figure 3. Detail of scene of high cloud in the long-wave IR: Cloud edge.

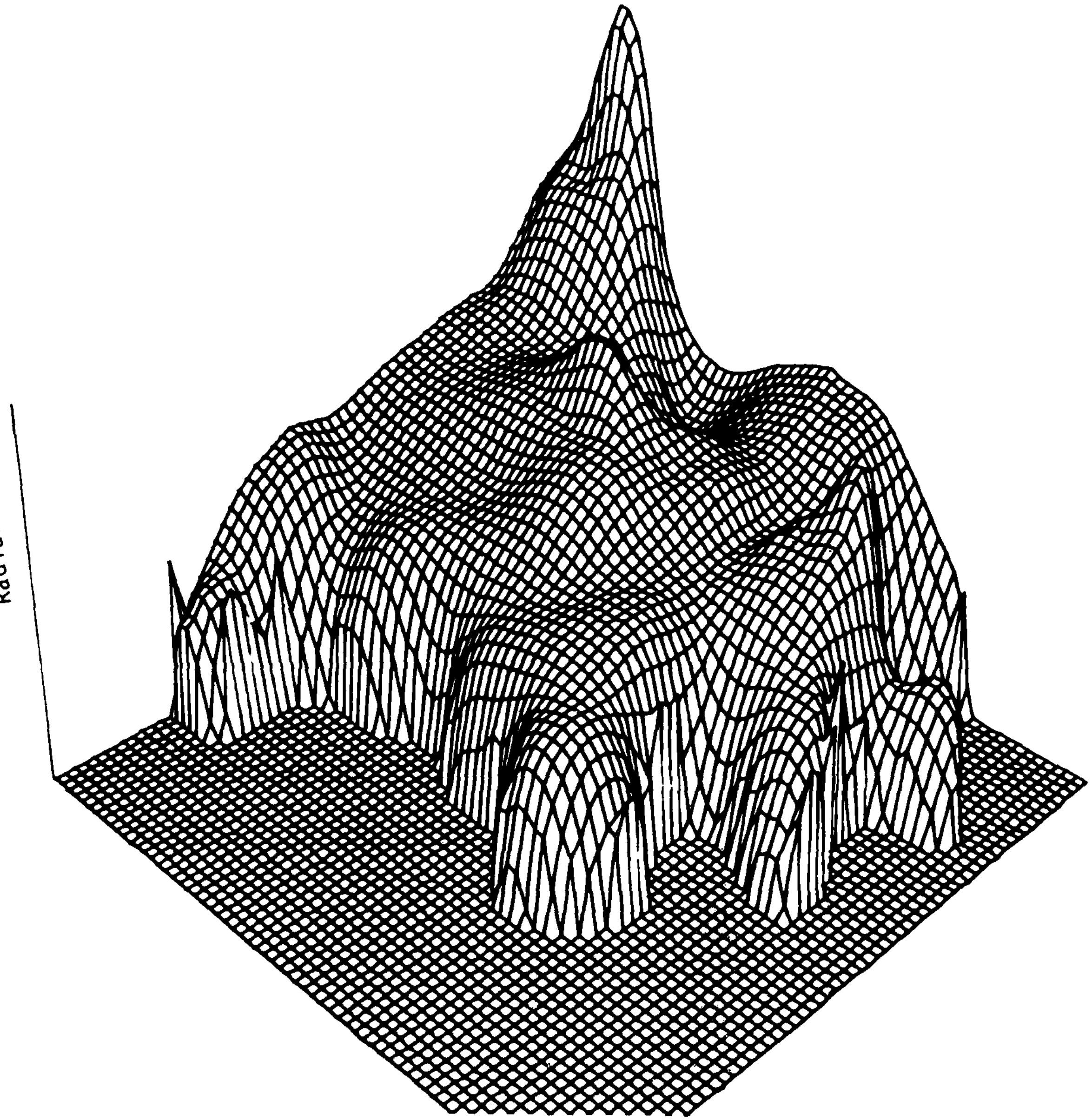


Figure 4. Detail of scene of low cloud in the middle IR: Cloud edge.

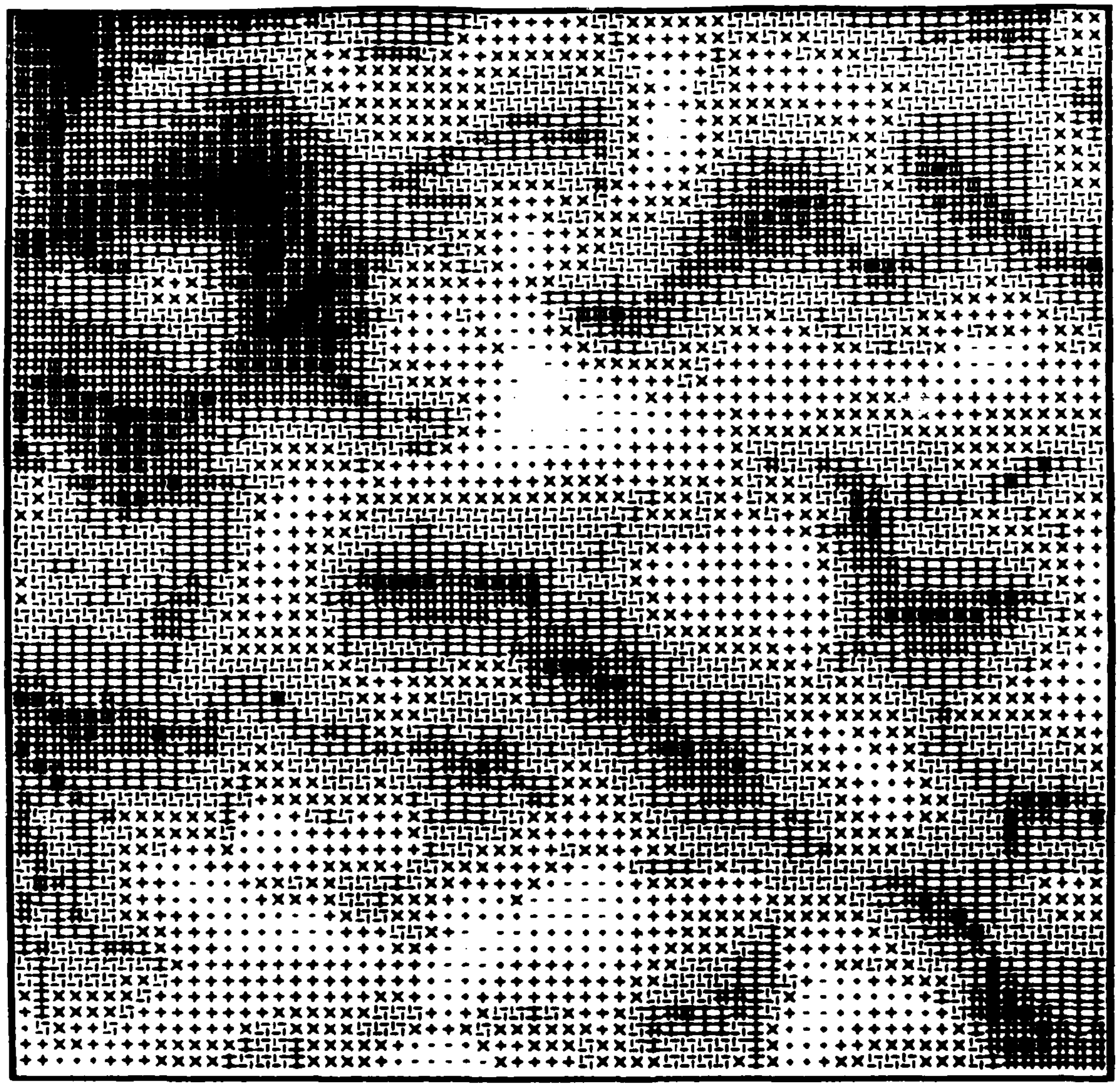


Figure 5. Detail (64 x 64 pixels) of PRA scene of high cloud in the middle IR. Top of the cloud, showing texture. Dark is cold. Note the apparent filamentary structures.

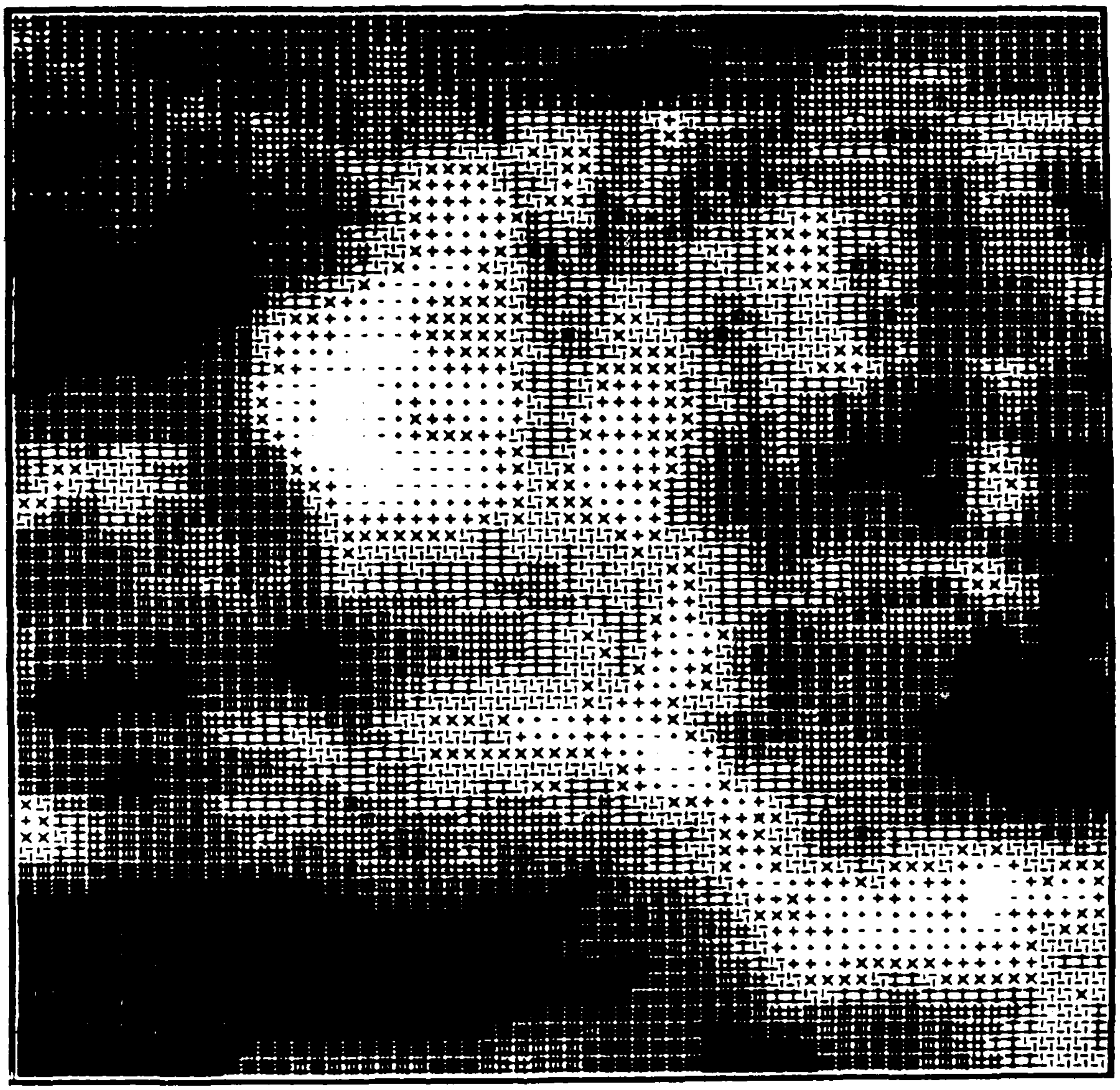


Figure 6. Section (64 x 64 pixels) of a Daedalus measured image of cloud over mountain in the thermal IR. Some possible filamentary features appear (it helps to stand away from the image).

CHARACTERISTIC DIMENSION OF OPTICAL DEPTH IN CLOUD

Extinction K = 2 x Condensed Water Content / Average Droplet Radius
(Assumed average droplet radius = 10 microns)

Altitude (km)	Temp (K)	Pressure (mb)	H2O SVP (mb)	CWC (g/m3)	Ext. k (cm-1)	Length (m)
1	282	899	11.4	9.16	18.(-3)	0.5
2	275	796	7.1	5.7	11.(-3)	0.9
3	269	701	4.5	3.6	7.2(-3)	1.4
4	262	617	2.65	2.1	4.2(-3)	2.3
5	256	541	1.37	1.1	2.2(-3)	4.5
6	249	472	0.69	0.55	1.1(-3)	9.0
7	242	411	0.35	0.28	5.6(-4)	18.
8	236	356	0.18	.145	2.9(-4)	35.
9	230	308	.091	.073	1.5(-4)	68.
10	223	265	.039	.031	6.2(-5)	161

Caveat - these numbers are based on certain assumptions. Very wide deviations from these numbers occur, in both directions.

The condensed water content is obtained by assuming that the amount of water or ice in the cloud volume is equal to the amount of vapor. It may be much more or less. While we indicate CWC's of less than 0.1 gram per cubic meter at high altitude, some measurements have reported cirrus contents as high as 0.25 g/m3, which in turn would indicate shorter characteristic optical lengths, and thus smaller, sharper features in cirrus.

The atmosphere used is the US standard atmosphere. The temperature profile may vary considerably from this, of course. And at low temperatures, the saturation humidity is a very strong function of temperature.

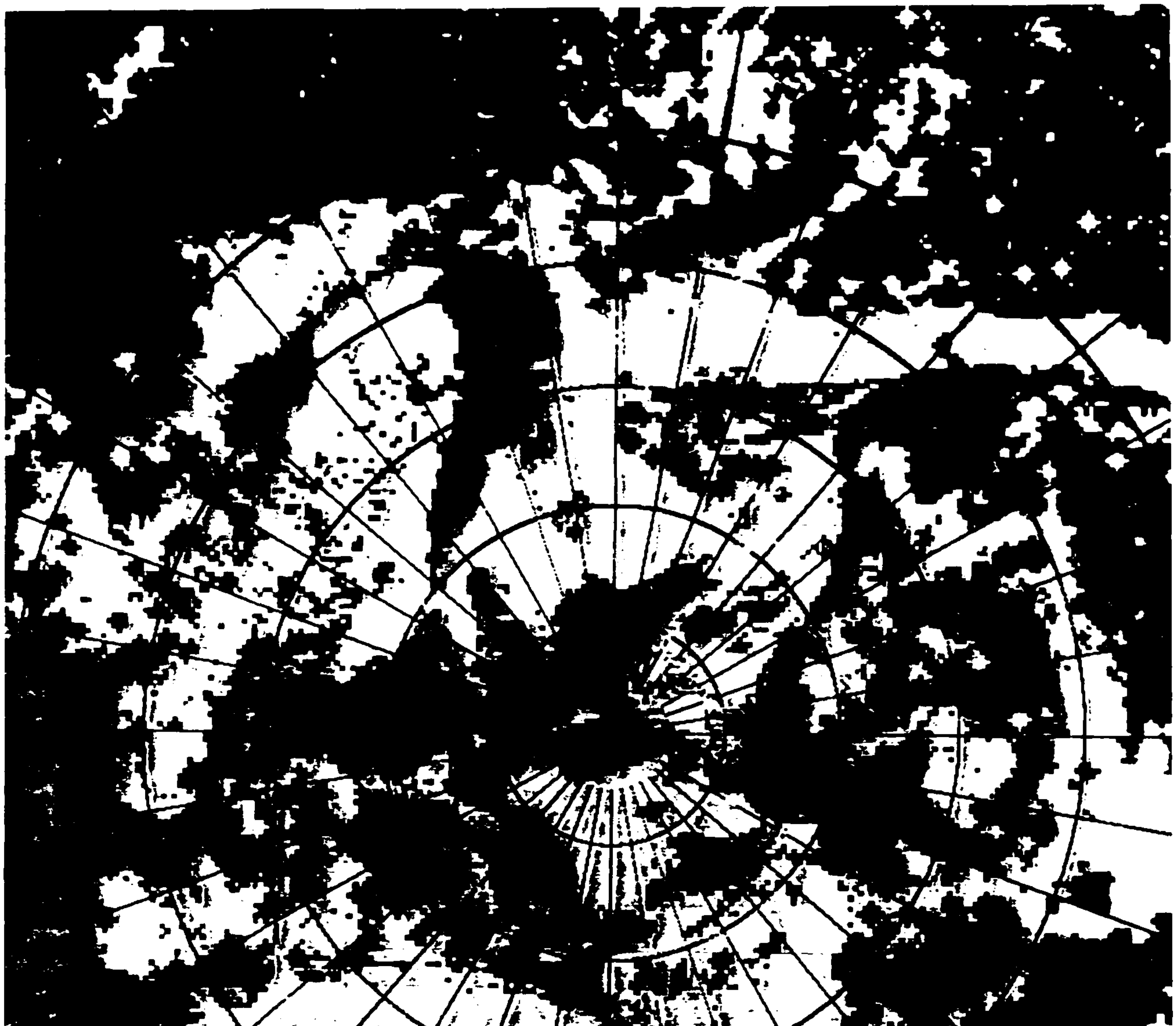
The droplet size is common for moderately aged continental clouds. Where clouds have formed very recently (consider the example of the clouds formed by dropping a piece of dry ice into a glass of water) droplets can be much smaller and characteristic optical lengths much shorter.

REAL-TIME NEPHANALYSIS (RTNEPH)

Lt Col William M. Cox
Air Force Global Weather Central

R T N E P H

REAL-TIME NEPHANALYSIS



INPUT DATA

* CONVENTIONAL

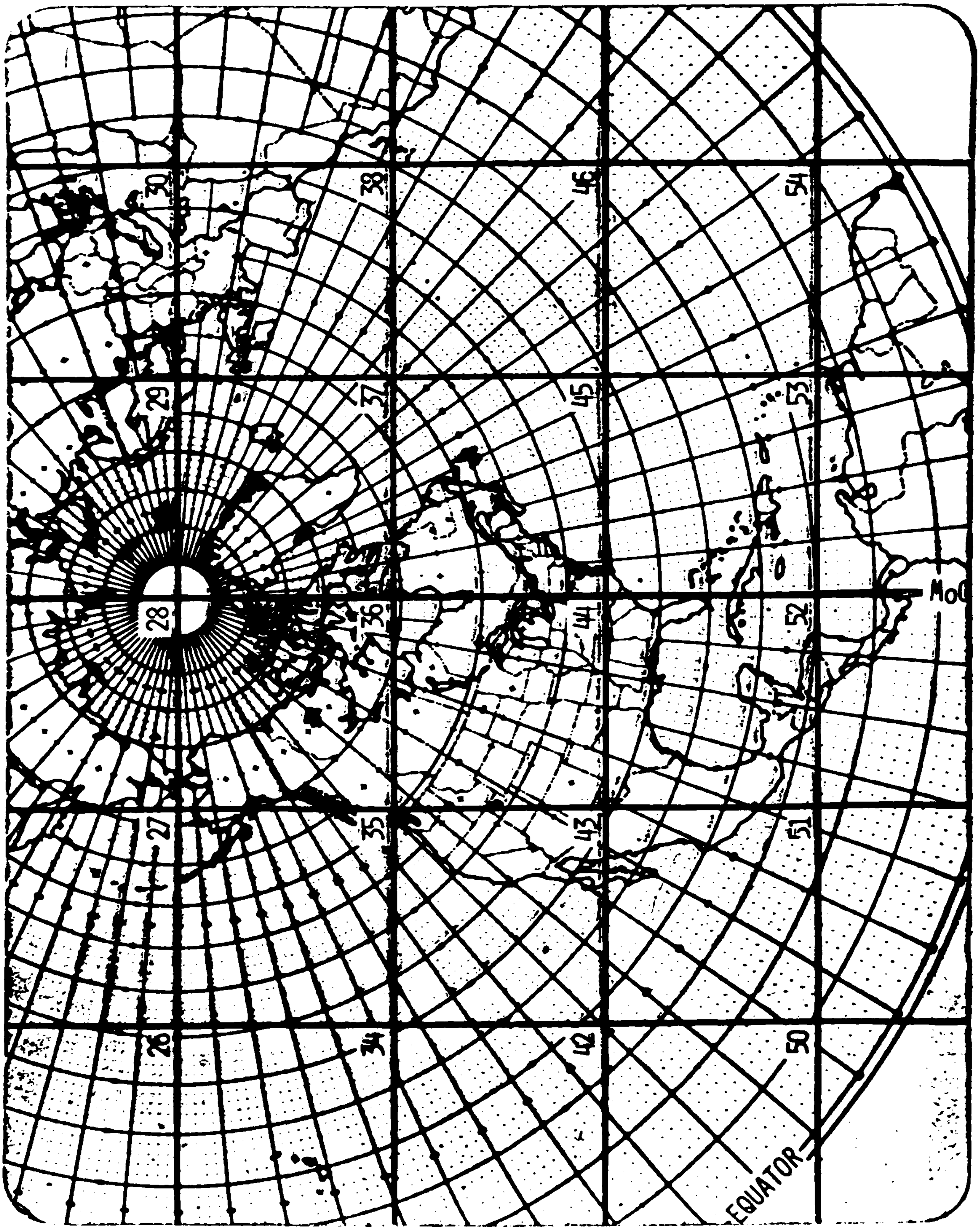
  SURFACE OBS
  PILOT REPORTS
  RAOBS

* SATELLITE

  VIDEO (0.4-1.1 UM)
  INFRARED (8-13/10.8-12.5 UM)

INPUT DATA

* PERSISTENCE
* BOGUS (MAN-MACHINE MIX)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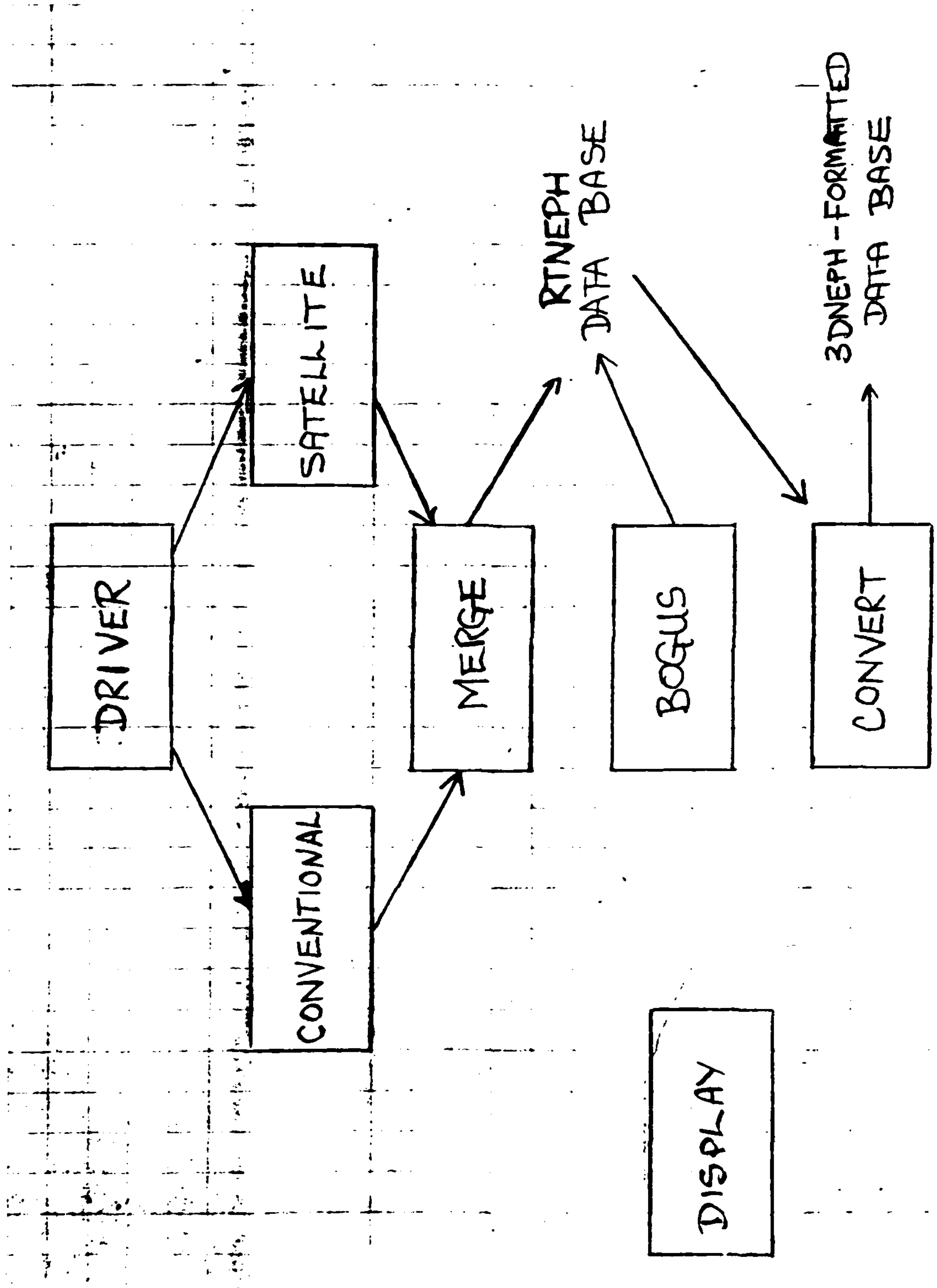
EQUATOR

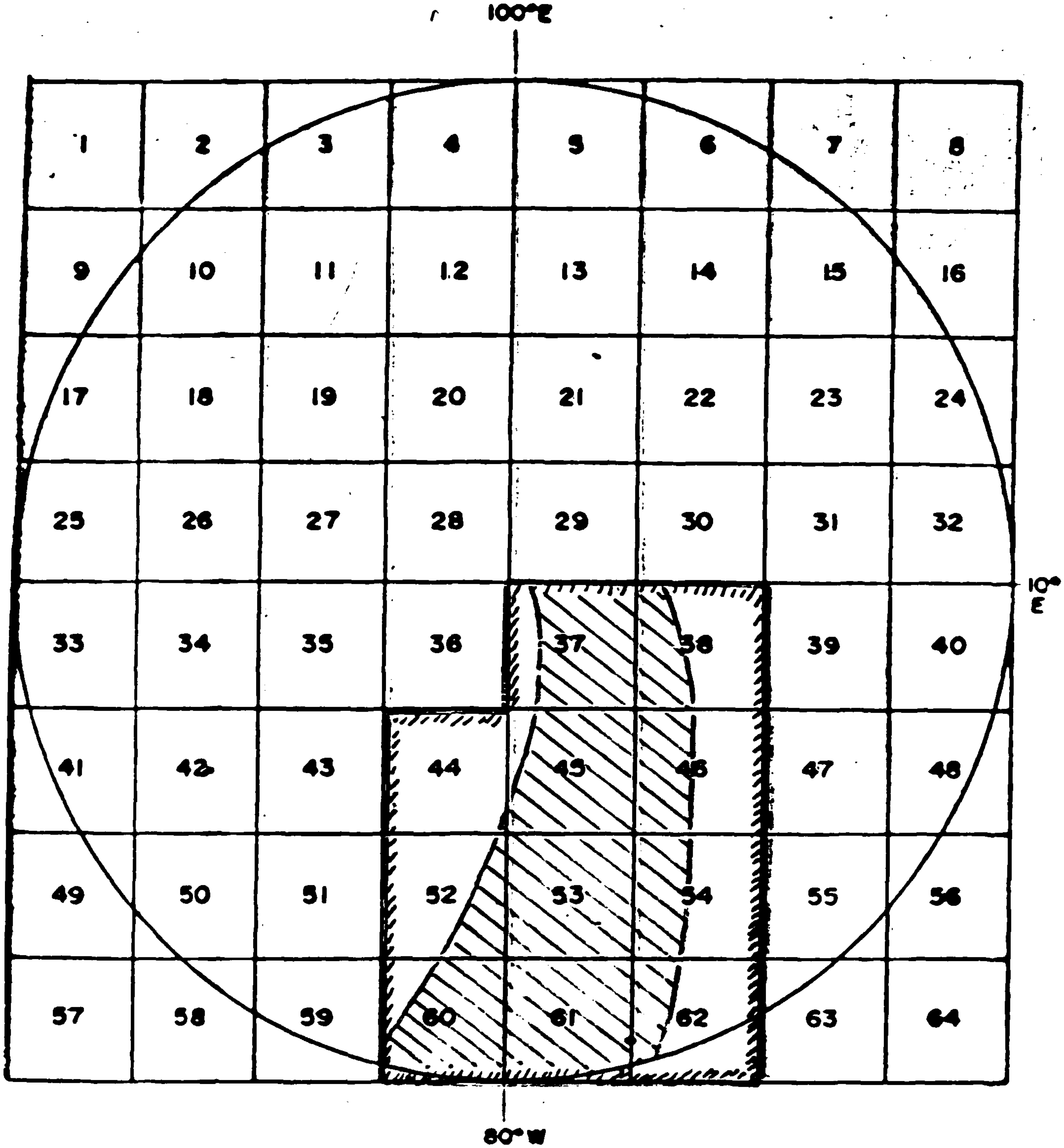

DRIVER
SATELLITE
CONVENTIONAL
MERGE
RTNEPH DATA BASE
BOGUS
CONVERT
3DNEPH-FORMATTED DATA BASE
DISPLAY

CONVENTIONAL PROCESSOR

- PROCESSES SURFACE REPORTS, AIRCRAFT REPORTS, RAOBS
- PRODUCES ONE "BEST REPORT" FOR EACH 25NM GRID POINT
- LARGE MAJORITY OF GRID POINTS HAVE NO BEST REPORTS

SATELLITE PROCESSOR

- PROCESSES INFRARED OR VISUAL DATA
- PROCESSES UP TO FOUR METSATS (OTHER CONSTRAINTS LIMIT TO TWO CURRENTLY)
- INFRARED AND VISUAL ANALYSES MERGED LATER BY RTNEPH MERGE PROCESSOR
- BASED ON 8X8 PIXEL ARRAY IN SATELLITE GLOBAL DATA BASE


100°E
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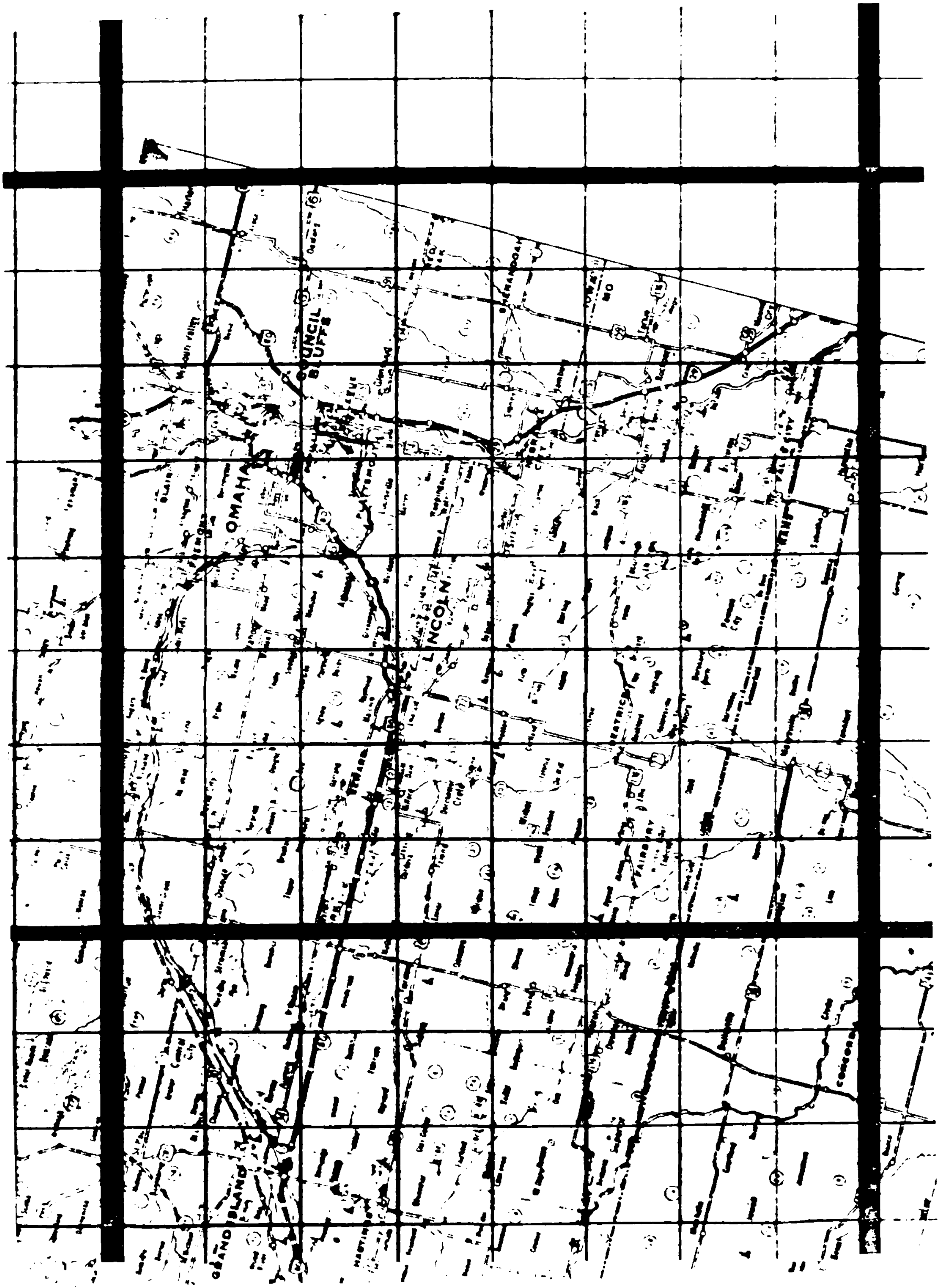
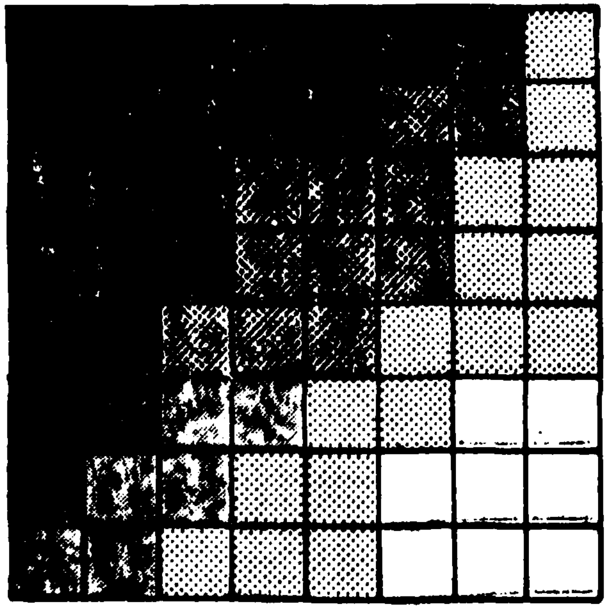
10°E
80°W


COUNCIL BLUFFS
OMAHA
LINCOLN



GRAYSHADES

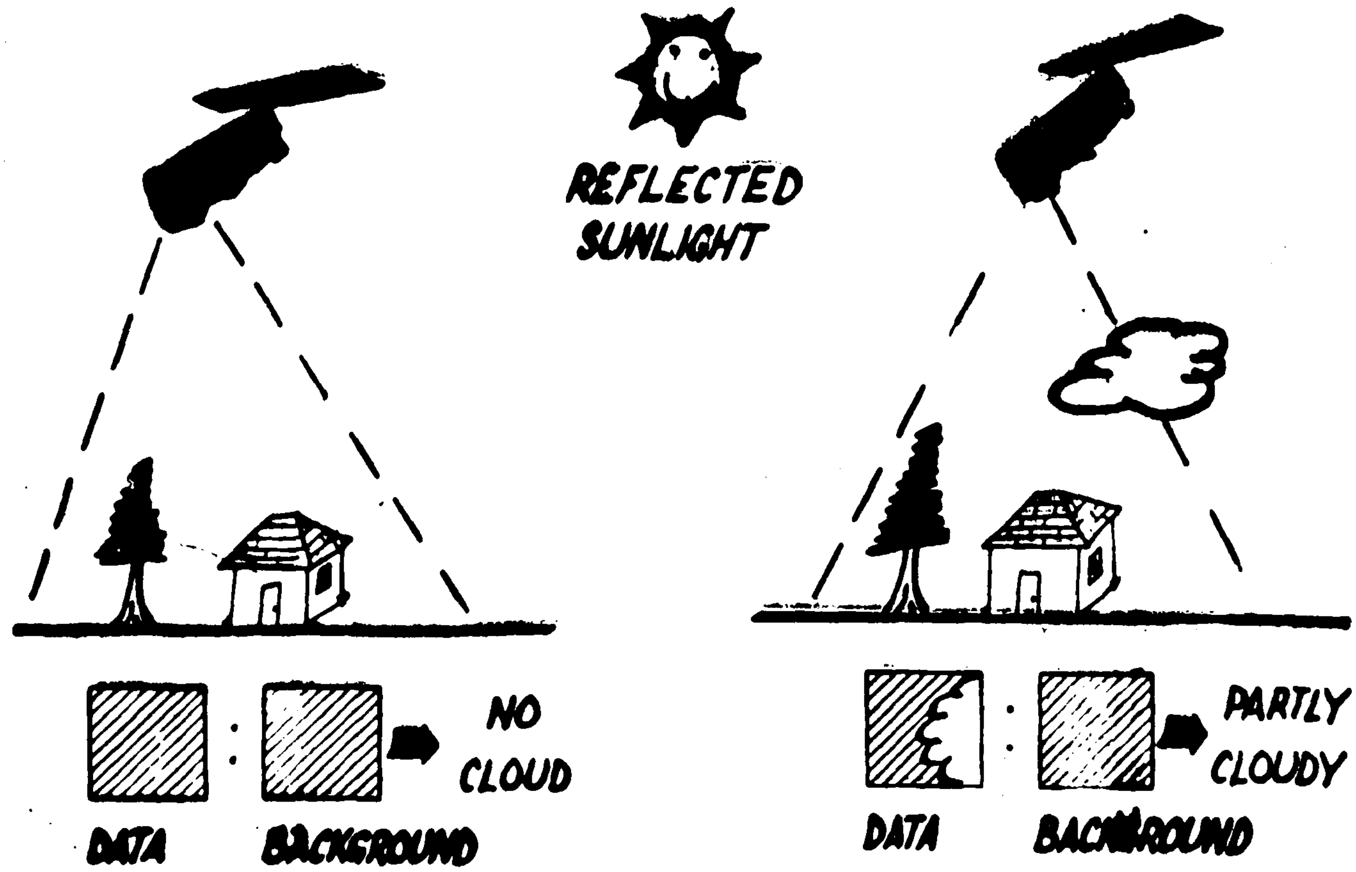
3	3	3	3	12	12	19	34
3	3	3	3	12	19	19	34
3	3	12	19	19	19	34	34
3	3	12	19	19	19	34	34
3	3	19	19	19	34	34	34
3	3	19	19	34	34	50	50
12	19	19	34	34	50	50	50
19	19	34	34	34	50	50	50

QUANTIZED DATA

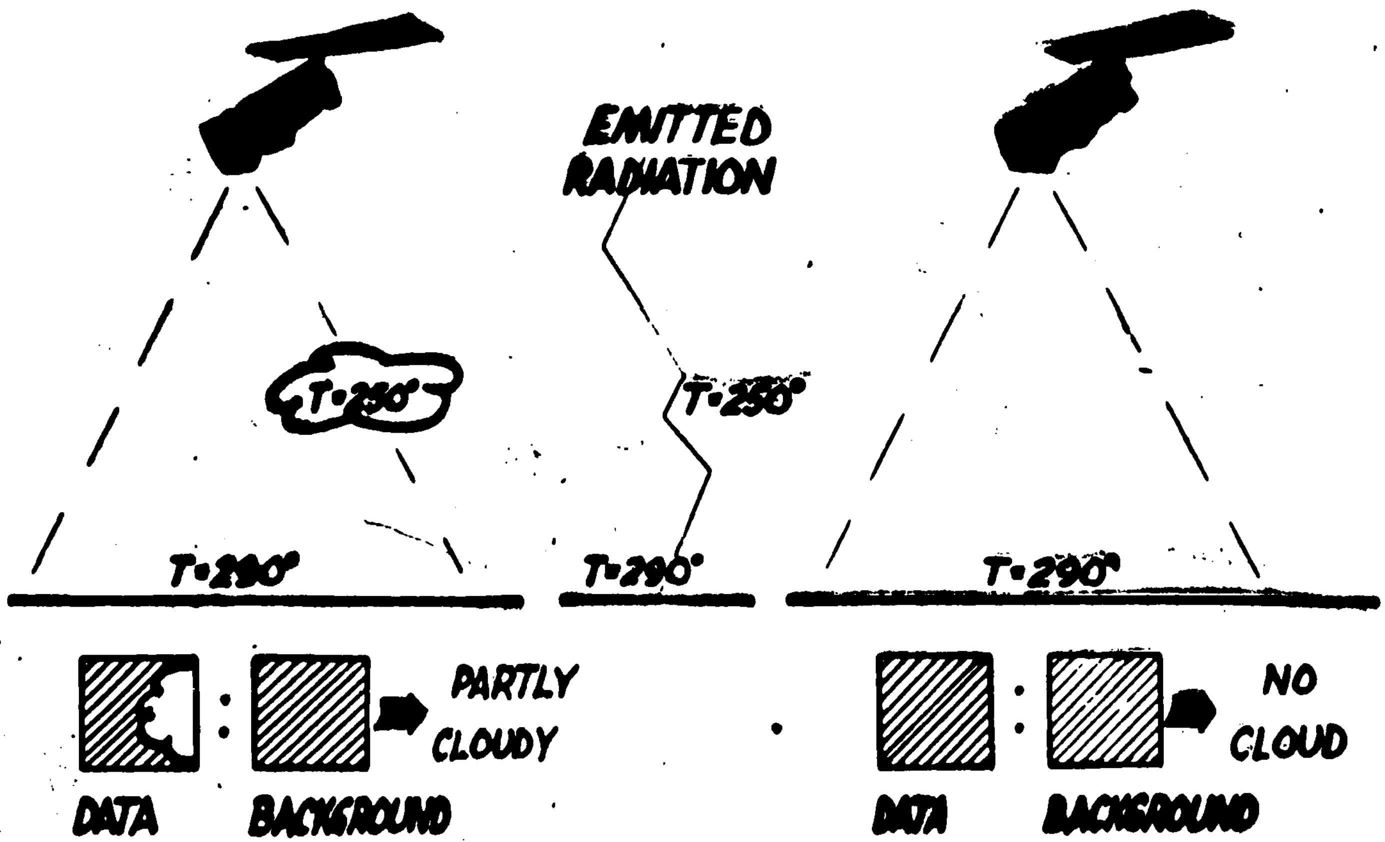
FIRST ORDER STATISTICS

COMPARISON WITH A BACKGROUND

PROCESSING VISUAL DATA



IR DATA PROCESSING



MERGE PROCESSOR

BUILDS FINAL ANALYSIS BY MERGING ANALYSES FROM SATELLITE AND CONVENTIONAL PROCESSORS

- -INCREASE INFLUENCE OF SPARSE SURFACE REPORTS BY SPREADING THEM 3 GRIDPOINTS IN ALL DIRECTIONS
- -CHOOSE EITHER SATELLITE DATA OR SPREAD REPORTS
  - -TIMELY DATA HAS PRIORITY
  - -SOME DATA ARE COMBINED
- -IF NO NEW DATA AVAILABLE, USE PERSISTENCE

BOGUS

1. DATA BASE INSPECTION (WS)

2. CORRECTION OF DEFICIENCIES

3. WINDOW ANALYSES ONLY

CONVERT RTNEPH TO 3DNEPH

* DETERMINE THE 3DNEPH CLOUD LAYERS TO FILL

* ALTER LAYER AMOUNTS UNTIL THE 3DNEPH LAYER SUMMING PROPERTY IS VALID

DATA BASE

TOTAL

LAYERS

AMOUNT

BASES-TOPS

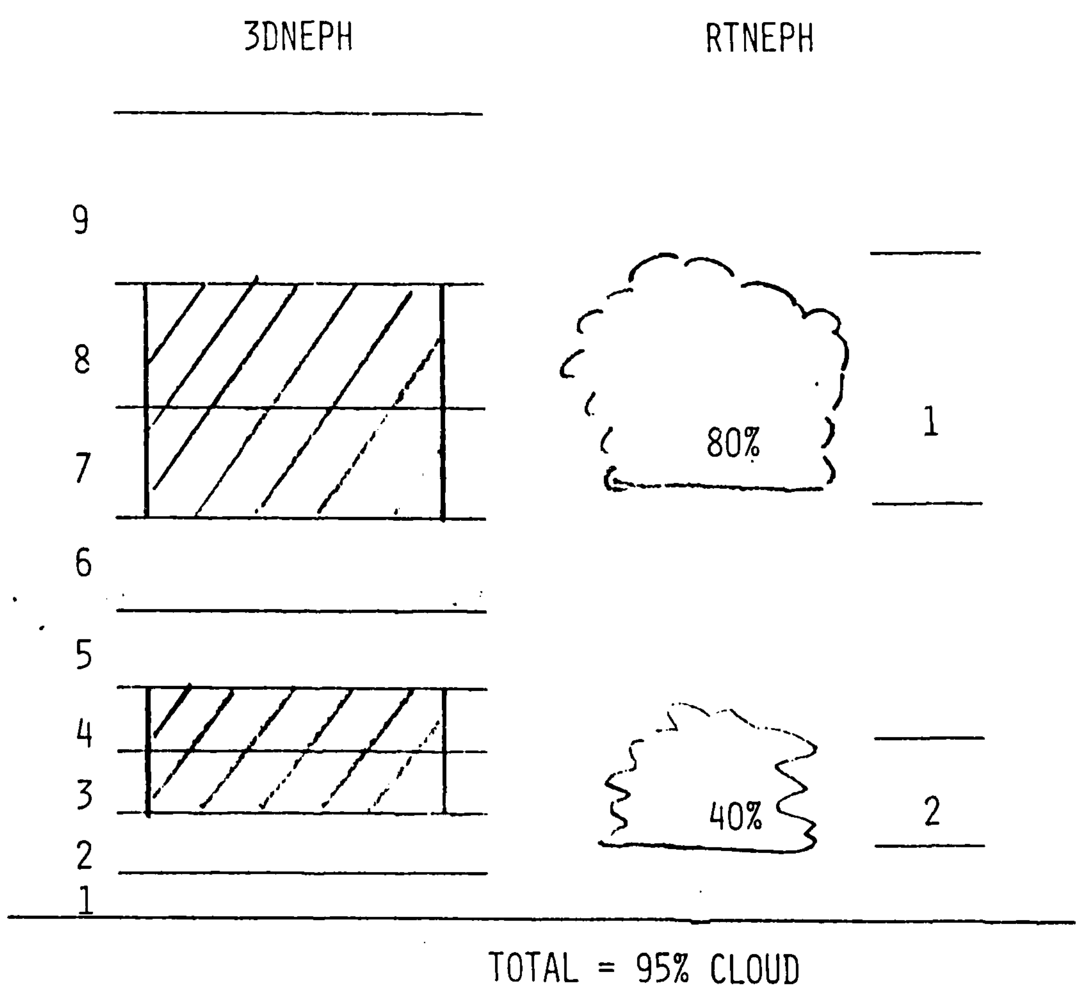
TYPE

THIN

WEATHER

WMO CODE

FLAGS



MAJOR CHANGES

- 4 VARIABLE CLOUD LAYERS vice 15 FIXED LEVELS
- BETTER RESOLUTION OF CLOUD BASES
- VISIBILITY RETAINED
- INTENSITY OF PRESENT WEATHER ELEMENTS RETAINED
- STORAGE OF PREDOMINANT DATA SOURCE FLAG
- STUB FOR EARTH vs SKY COVER

CLOUD DATA BASES FROM THE INTERNATIONAL
SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP)

Herbert Jacobowitz
NOAA/NESDIS

CLOUD DATA BASES FROM THE INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP)

The establishment of an adequate global cloud climatology is the first program sanctioned by the World Climate Research Program. The understanding of the role of clouds in climate and the proper representation of cloud-radiation feedback in models is of primary importance to climate prediction.

The scientific objectives of the ISCCP are to 1) produce a reduced resolution visible and infrared calibrated and normalized global radiance data set from which cloud parameters can be derived, 2) foster basic research on techniques for inferring the physical properties of clouds from the data set and 3) to promote research using the ISCCP data in an improved understanding of the earth radiation budget and inferring other climate parameters.

Data specification for 30 day averages calls for obtaining the fraction of low, middle, cirrus and deep convection clouds to better than 5% and for the total cloud cover to better than 3%. Also, the heights are to be determined to better than 1 km for cloud layers other than low level clouds where 0.5 km is the precision level. Cloud top temperatures are to be determined to better than 1°K. Spatial averages are to be over approximately 250 km by 250 km boxes with sampling 8 times a day for a 5 year period. At present GOES-West, GOES-East, METEOSAT, and GMS are the participating meteorological satellites and the NOAA 7 polar orbiter.

It has been concluded that surface and atmospheric correlative data are essential to the determination of the cloud climatology which will be archived along with the reduced radiance data set and cloud parameters set.

The First ISCCP Regional Experiment (FIRE) is the national program in response to some of the research goals of the ISCCP. Its emphasis is on the way clouds are parameterized in climate models due to an inadequate knowledge of cloud formation, maintenance and dissipation. An interagency program has been set up to deal with 1) validating the cloudiness and radiation parameterizations in climate models, 2) characterizing the marine boundary layer clouds, 3) determining the characteristics that maintain cirrus clouds, 4) deriving the statistics of the cloud physical radiation properties and 5) assembling the data set in a central facility to permit independent study.

While initial activity has already begun on the FIRE, NOAA is hopeful in playing a major role in the time period FY86 - FY90 if our initiative is passed by Commerce, OMB and the Congress.

Cloud Data Bases

from the

International Satellite Cloud Climatology Project

(ISCCP)

presented by

Dr. Herbert Jacobowitz, NOAA/NESDIS

June 27, 1984

2

REPORT OF THE FIRST SESSION OF THE JOINT SCIENTIFIC COMMITTEE, 1980

"Important Aspects of Cloudiness and Radiation Related to the World Climate Research Program" Are:

- Sensitivity of Climate to Cloud-Radiation Feedback
- How to Predict Generation of Clouds in Climate Models
- Empirical Studies of Dependence of Climate on Clouds
- Establishment of Adequate Cloud Climatology

NASA HQ EE84-734 (1)
1-16-84

3

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP)

SCIENTIFIC OBJECTIVES

- TO PRODUCE REDUCED RESOLUTION VISIBLE AND INFRARED CALIBRATED AND NORMALIZED GLOBAL RADIANCES CONTAINING BASIC INFORMATION ON THE RADIATIVE PROPERTIES OF THE ATMOSPHERE, FROM WHICH CLOUD PARAMETERS CAN BE DERIVED,

- TO FOSTER BASIC RESEARCH ON TECHNIQUES FOR INFERRING THE PHYSICAL PROPERTIES OF CLOUDS FROM CONDENSED RADIANCES, AND TO APPLY RESULTING EXPERIMENTAL ALGORITHMS TO DERIVE AND VALIDATE CLOUD PARAMETERS FOR IMPROVING THE PARAMETERIZATION OF CLOUDS IN CLIMATE MODELS, AND

- TO PROMOTE RESEARCH USING ISCCP DATA IN CONTRIBUTING TO IMPROVED UNDERSTANDING OF THE EARTH'S RADIATION BUDGET (TOP OF THE ATMOSPHERE AND SURFACE) AND FOR INFERRING OTHER IMPORTANT CLIMATE PARAMETERS SUCH AS PRECIPITATION.

NASA HQ EE84-695 (1)
1-12-84

DATA SPECIFICATION FOR THE INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY

PARAMETERS--SPATIAL AND TEMPORAL AVERAGES AND VARIANCES (OR ANOTHER STATISTICAL MEASURE OF THE SHAPE OF THE TEMPORAL DISTRIBUTION) ARE REQUIRED FOR EACH OF THE FOLLOWING PARAMETERS.

AMOUNTS	PRECISION (30-DAY AVERAGES)
TOTAL CLOUD AMOUNT (FRACTION) *	±0.03
CIRRUS CLOUD AMOUNT (FRACTION) *	±0.05
MIDDLE CLOUD AMOUNT (FRACTION)	±0.05
LOW CLOUD AMOUNT (FRACTION)*	±0.05
DEEP CONVECTIVE CLOUD AMOUNT (FRACTION)	±0.05
HEIGHTS	
CIRRUS CLOUD-TOP HEIGHT (km) *	±1.00
MIDDLE LEVEL CLOUD-TOP HEIGHT (km)	±1.00
LOW-LEVEL CLOUD-TOP HEIGHT (km)	±0.50
DEEP CONVECTIVE CLOUD-TOP HEIGHT (km)	±1.00
CLOUD TOP TEMPERATURE (°K) FOR EACH CLOUD CATEGORY*	±1.00

CLOUD OPTICAL DEPTH

CLOUD SIZE DISTRIBUTION

AVERAGE NARROW BAND RADIANCES (VIS AND IR) *

SPATIAL AVERAGING--THE INFORMATION IS TO BE AVERAGED OVER APPROXIMATELY 250--km BY 250-km BOXES

TIME SAMPLING--EVERY 3 HOURS, i.e., 8 TIMES A DAY, CENTERED AROUND THE SYNOPTIC OBSERVATION TIMES.

TIME AVERAGING--THE GLOBAL CLOUD CLIMATOLOGY SHOULD CONSIST OF 30-DAY AVERAGES FOR EACH OF THE 8 OBSERVING TIMES PER DAY.

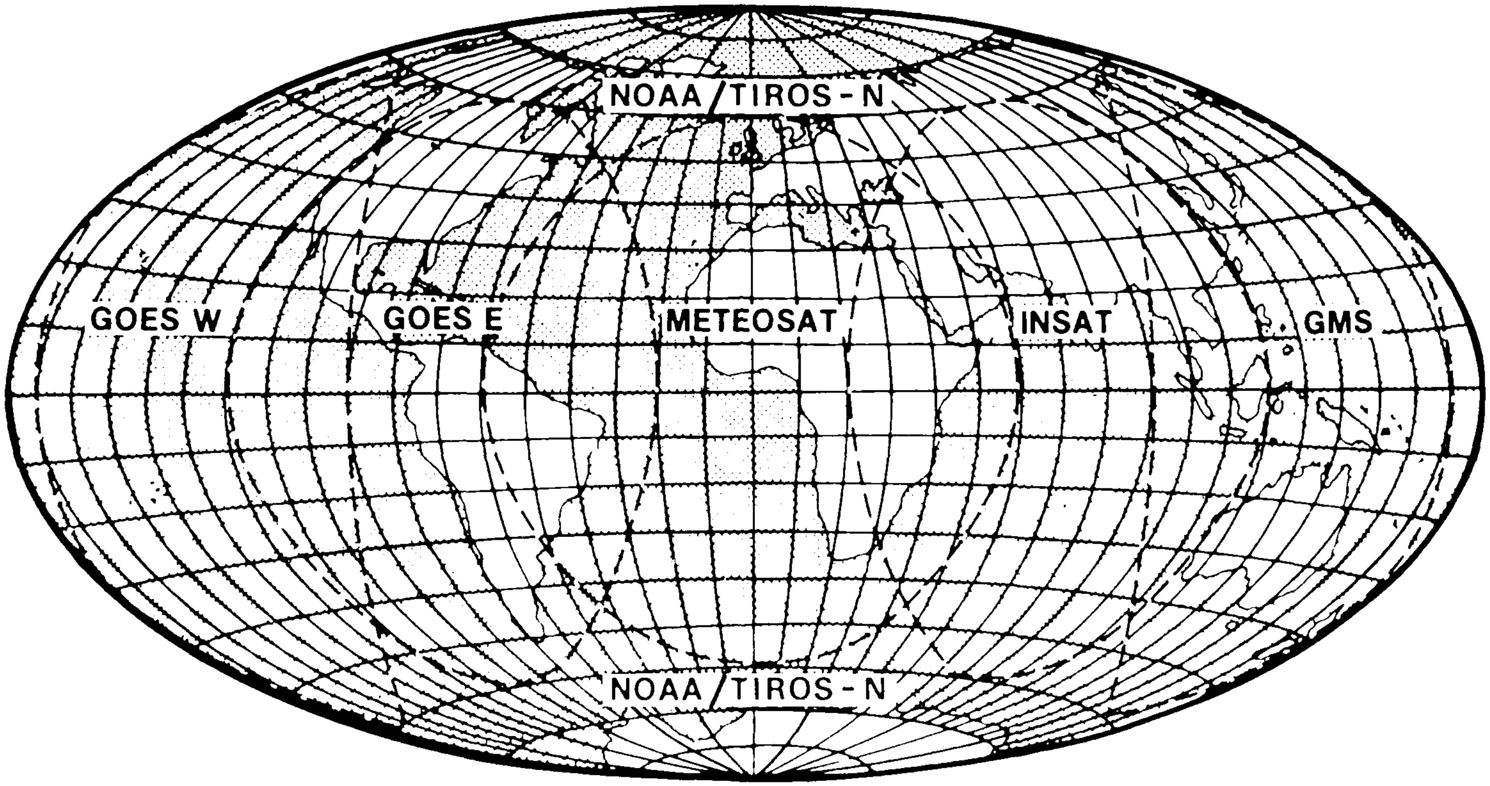
LENGTH OF TIME SERIES--5 YEARS

NASA HQ EE84-694 (1)
1-12-84

* HIGHEST PRIORITY

5

DATA PROCESSING SECTORS FOR THE INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP)



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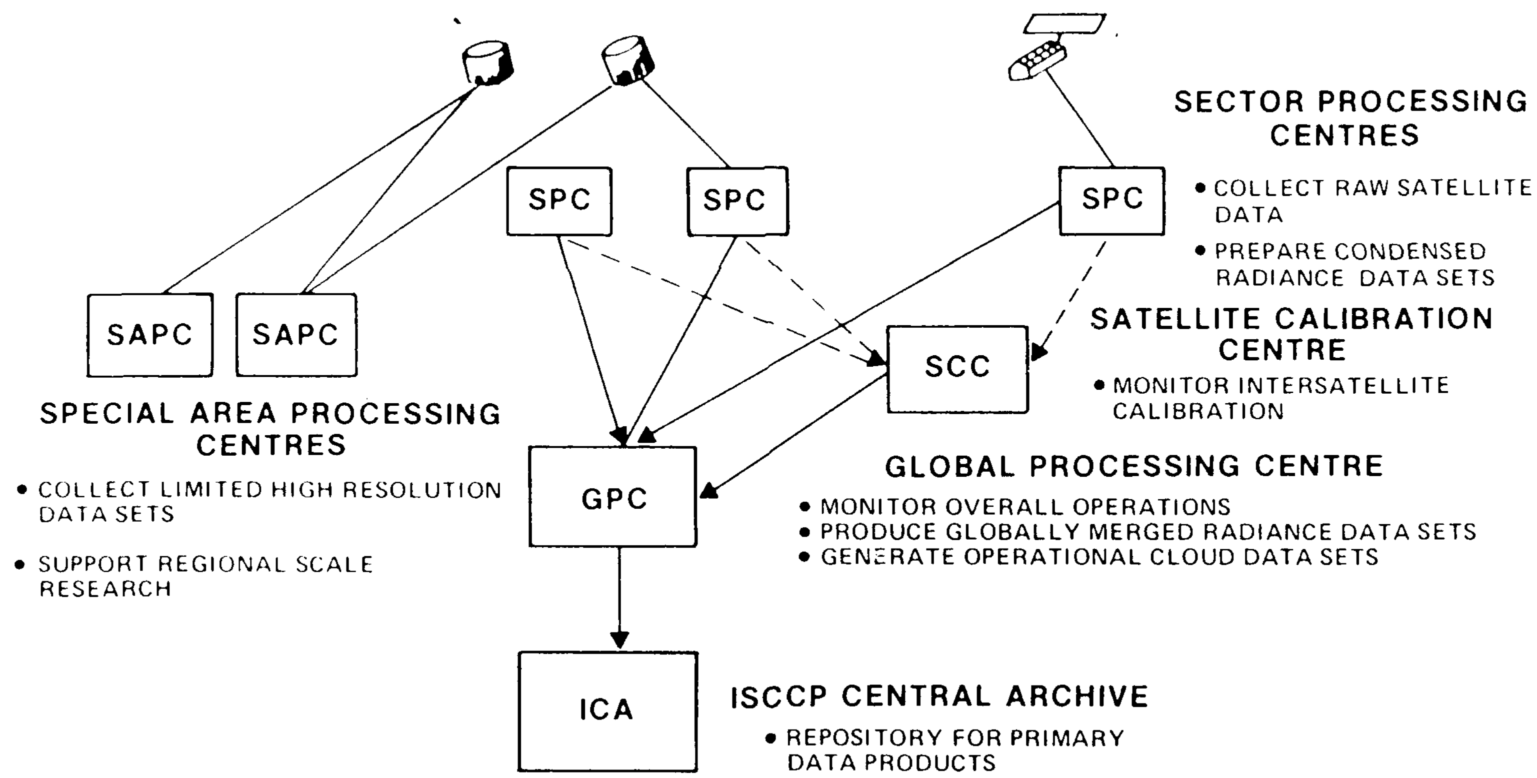
7 22 83

6

ISCCP DATA FLOW CONCEPT



NASA HQ EE83-1517 (1)
4-13-83

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT

DATA MANAGEMENT COMMITMENTS

SECTOR PROCESSING CENTRES (SPC):

METEOSAT	EUROPEAN SPACE AGENCY (ESOC/DARMSTADT)
GOES-E	CANADA (AES/ONTARIO)
GOES-W	U.S.A. (COLO. STATE UNIV./FT. COLLINS)
GMS	JAPAN (JMA/TOKYO)
INSAT	INDIA (TENTATIVE)
NOAA/TIROS N	U.S.A. (NOAA/WASHINGTON D.C.)

GLOBAL PROCESSING CENTRE (GPC):	U.S.A. (NASA/NEW YORK)
SATELLITE CALIBRATION CENTRE (SCC):	FRANCE (CMS/LANNION)
ISCCP CENTRAL ARCHIVE (ICA):	U.S.A. (NOAA/WASHINGTON D.C.)

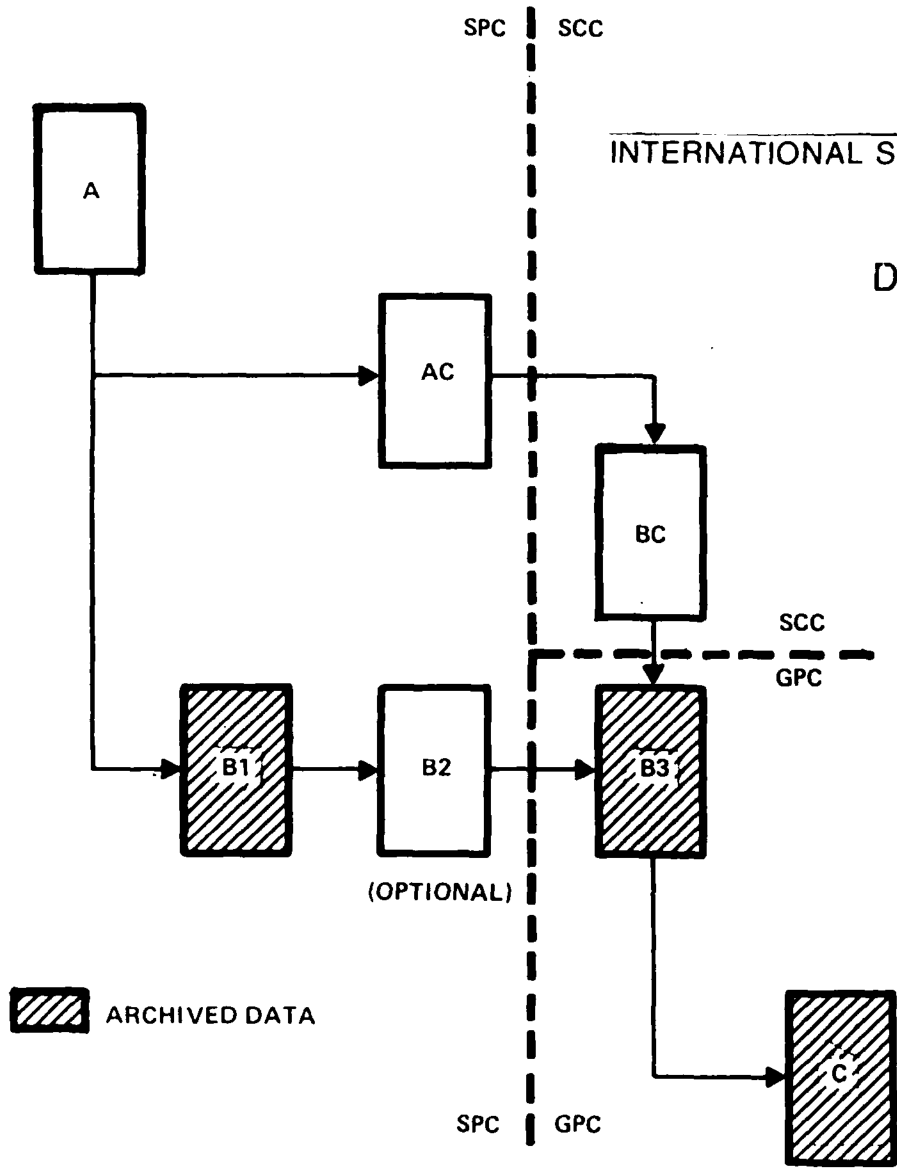
NOTES: UNIVERSITY OF COLOGNE, F.R.G ACTING SCC THROUGH NOV. 1983
UNIVERSITY OF WISCONSIN, U.S.A. ACTING SPC/GOES-E THROUGH MAR. 1984

NASA HQ EE84-701 (1)
1-12-84

NAME
CODE
FINAL APP'L

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT

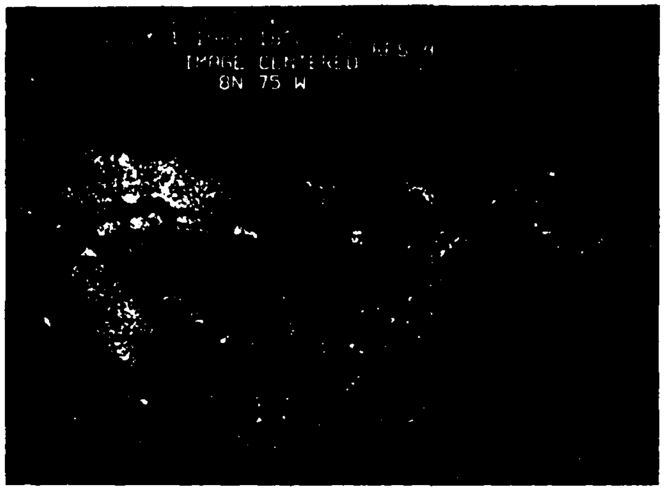
DATA STAGES



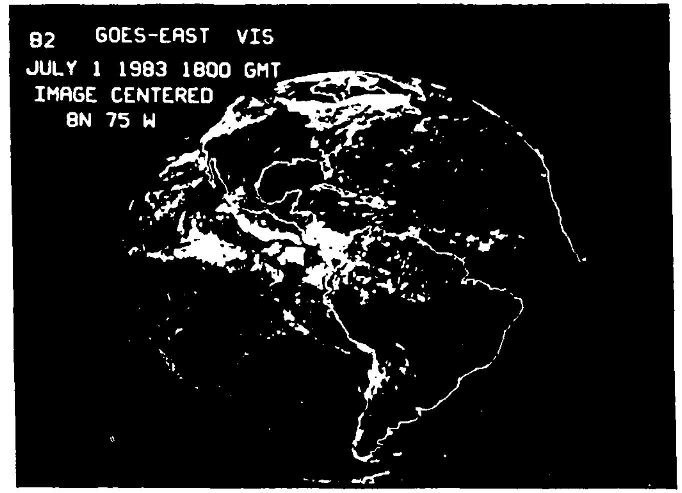
A	FULL RESOLUTION RAW VIS, IR IMAGE DATA
B1	REDUCED RESOLUTION 8-12 Km MATCHED VIS, IR IMAGE PAIRS
B2	SAMPLED B1 DATA 24-30 Km RESOLUTION
B3	GLOBALLY MERGED NORMALIZED VIS, IR RADIANCES
C	CLOUD PARAMETERS
AC	FULL RESOLUTION LIMITED AREA DATA FOR SATELLITE-TO-SATELLITE NORMALIZATION
BC	RADIANCE NORMALIZATION COEFFICIENTS

NASA HQ EE84-698 (1)
1-12-84

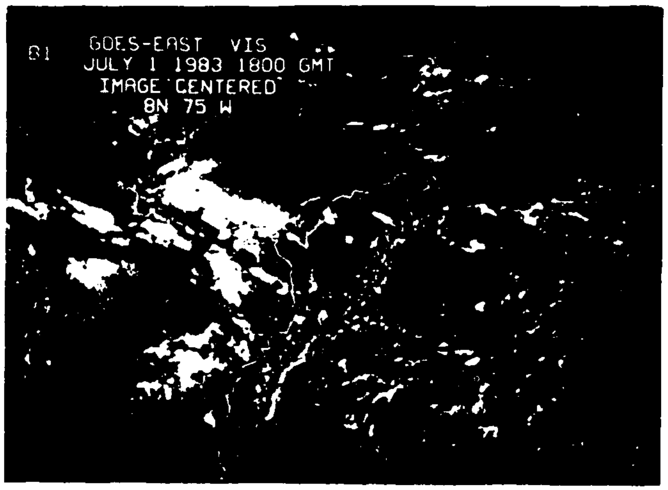
INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP)
DATA CONDENSATION (VIS)



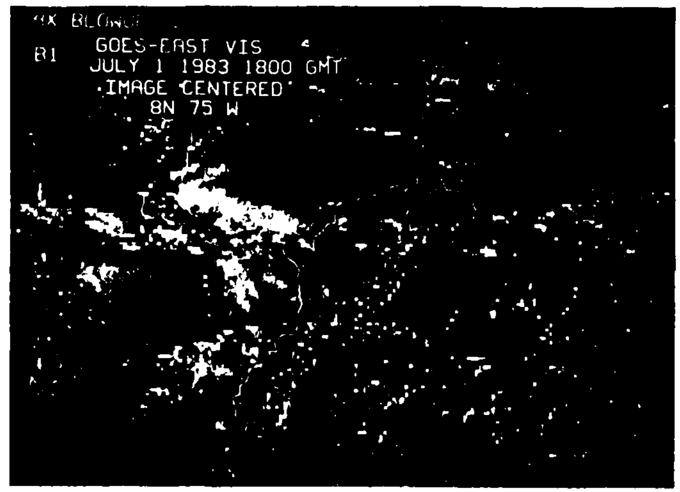
FULL RES



B2 RES



B1 RES

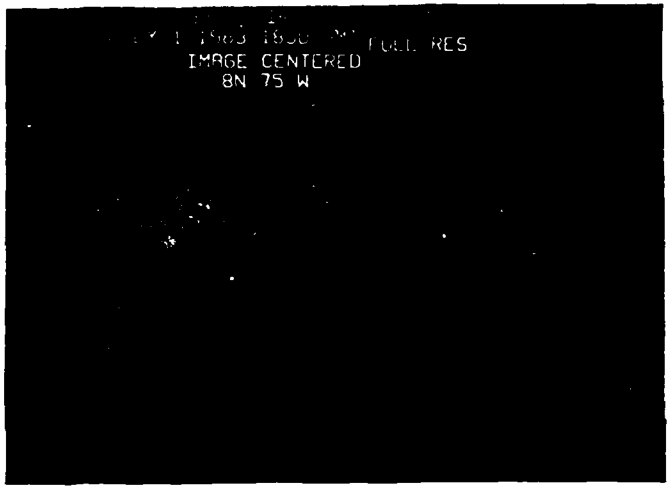


B2 RES

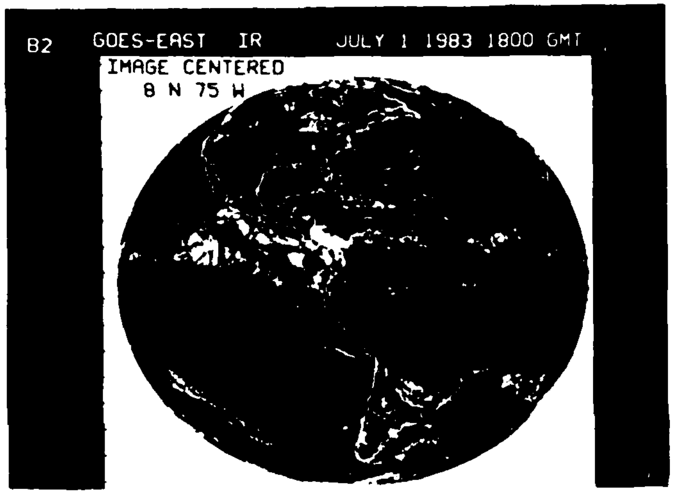
NASA HQ EE84-1077 (2)
2 16-84

10

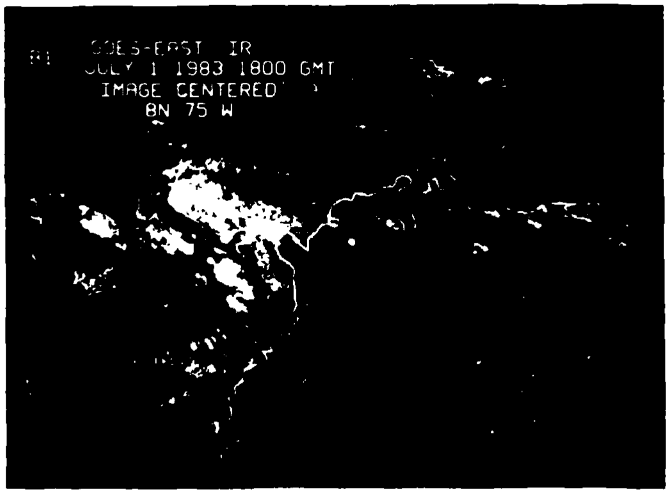
INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP) DATA CONDENSATION (IR)



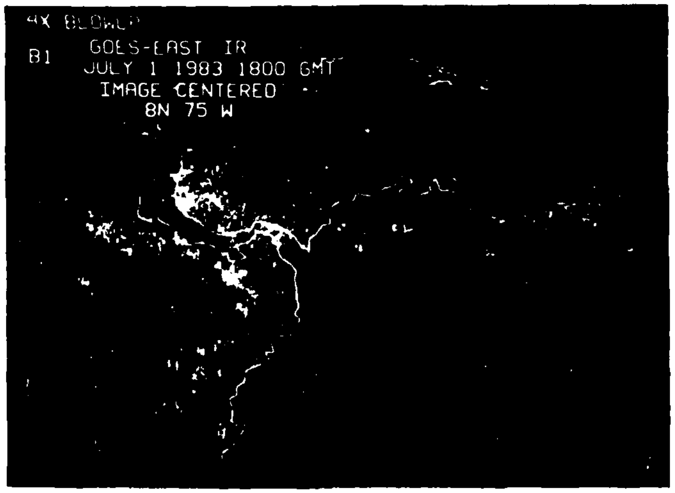
FULL RES



B2 RES



B1 RES



B2 RES

NASA HQ EE84-1076 (2)
2-16-84

ISCCP CLOUD ALGORITHM INTERCOMPARISON CONCLUSIONS

//

CLOUD DETECTION

- ALL METHODS DETECT CLOUDS BY VARIATION OF RADIANCES FROM EXPECTED (CLEAR SKY) VALUES
- STATISTICAL ANALYSIS METHODS EXHIBIT DEPENDANCE ON RADIANCE DISTRIBUTION IN SCENE AND ARE DIFFICULT TO ANALYZE IN COMPLICATED CASES
- ALL METHODS BENEFIT FROM CORRELATIVE DATA TO DEFINE CLEAR SKY RADIANCES, BUT USE OF THIS INFORMATION BY THRESHOLD TECHNIQUES IS SIMPLER
- THRESHOLD METHODS ARE BETTER UNDERSTOOD FOR COMPLICATED SCENES

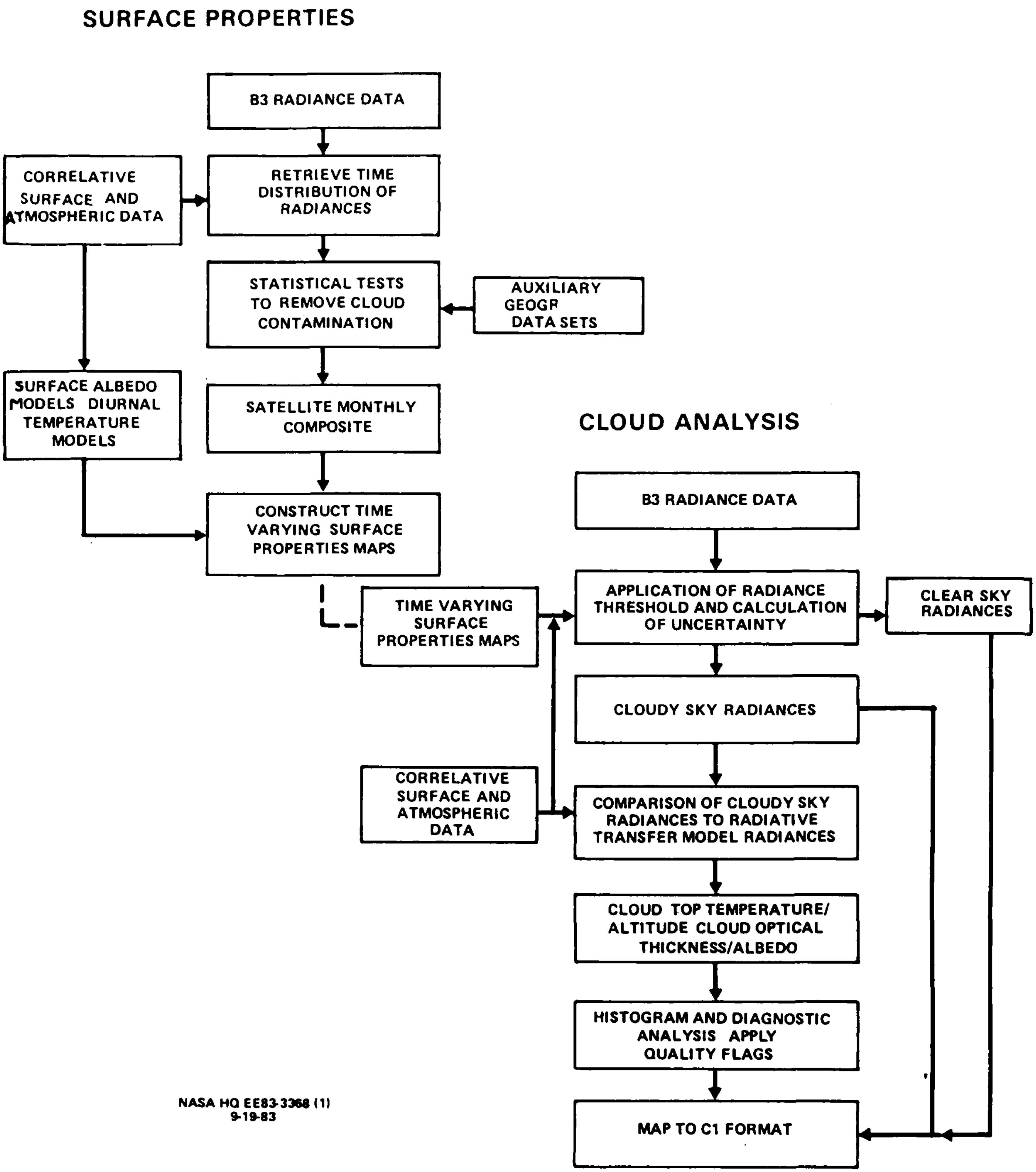
CLOUD AMOUNT

- ALL METHODS MUST CONTEND WITH PARTIALLY CLOUD COVERED IMAGE PIXELS
- ALL METHODS DEPEND ON CLOUD SIZE DISTRIBUTION AND CLOUD TYPE IN THE SCENE
- SIMPLEST METHOD IS COUNTING PIXELS WITH RADIANCE VALUES BEYOND A FINITE THRESHOLD WHICH ALLOWS FOR UNCERTAINTY ESTIMATE
- MOST METHODS ARE EQUIVALENT TO THIS METHOD, BUT PATTERNS REVEALED BY STATISTICAL METHODS MAY BE FURTHER EXPLOITED TO IMPROVE ESTIMATED CLOUD AMOUNT

RECOMMENDATIONS

- THRESHOLD METHOD IS SIMPLEST AND BEST DEVELOPED METHOD CURRENTLY AVAILABLE AND SHOULD BE ADOPTED AS PRELIMINARY ISCCP OPERATIONAL CLOUD ALGORITHM
- CONTINUING CLOUD ALGORITHM RESEARCH INCLUDING FURTHER INTERCOMPARISONS SHOULD BE GIVEN HIGH PRIORITY

NASA HQ ET84-780 (1)
1-17-84



NASA HQ EE83-3368 (1)
9-19-83

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP)

DATA SETS

SATELLITE RADIANCES (B3)

- ALL CHANNELS, VIS AND IR NORMALIZED TO AVHRR CHANNELS 1 AND 4.
- IMAGE PIXELS REPRESENT 8-12 KM RESOLUTION SAMPLED TO 24-30 KM SPACING
- EACH PIXEL TAGGED WITH LATITUDE, LONGITUDE, VIEWING GEOMETRY ANGLES

CORELATIVE DATA

- DATA INCLUDES SURFACE TEMPERATURE, PRESSURE, ALBEDO, TOPOGRAPHY AND LAND TYPE, SEA ICE, SNOW COVER, PROFILES OF ATMOSPHERIC TEMPERATURE AND WATER VAPOR, TOTAL OZONE COLUMN ABUNDANCE
- STANDARD EQUAL AREA GRIDS WITH RESOLUTION FROM 0.8^{o} (93 KM) TO 2.5^{o} (278 KM)
- TIME RESOLUTION FROM 3 HR TO ONE WEEK

CLOUD PARAMETERS (C)

- DATA INCLUDES CLOUD AMOUNT, OPTICAL THICKNESS, CLOUD TOP TEMPERATURE AND ALTITUDE FOR TOTAL, LOW, MIDDLE, HIGH, CIRRUS AND DEEP CONVECTIVE CLOUD TYPES
- ADDITIONAL DIAGNOSTICS INCLUDE VARIANCES, UNCERTAINTY ESTIMATES, AND HISTOGRAMS OF RADIANCES AND CLOUD PARAMETERS
- STANDARD EQUAL AREA GRIDS WITH 3 HR AND 2.5^{o} (APPROX. 250 KM) RESOLUTION
- SOFTWARE ON DATA TAPE ALLOWS REMAPPING TO MEET USER-SPECIFIC REQUIREMENTS
- CORRELATIVE DATA (USED IN CLOUD RETRIEVALS) AND AVERAGE TOTAL AND CLEAR SKY RADIANCES REPORTED

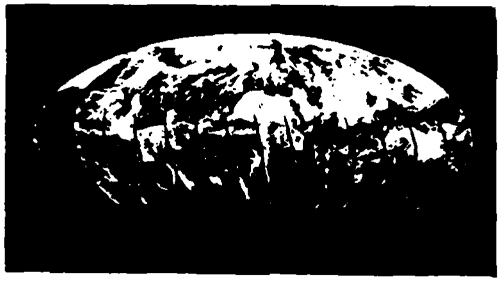
NASA HQ ET84-777 (1)
1-17-84

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP) FIRST RESULTS (1 JULY 1983)—VISIBLE (B2)

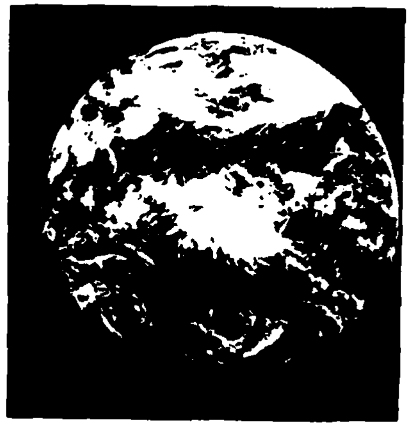
METEOSAT

INSAT

GOES-E



NOAA-7



GMS

GOES-W

NASA

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT

RESEARCH STRATEGY

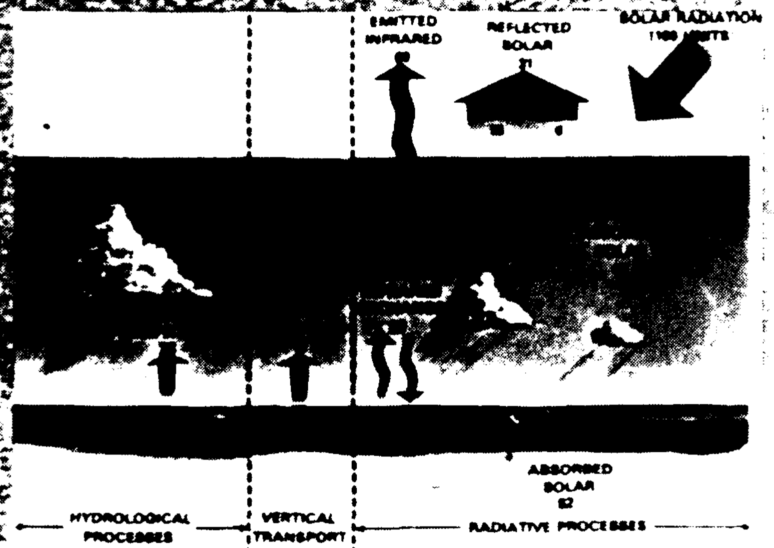
- REGIONAL EXPERIMENTS TO DEVELOP AND TEST NEW CLOUD AND RADIATION PARAMETERIZATION METHODS FOR CLIMATE MODELS
- GLOBAL AND REGIONAL INTERCOMPARISONS BETWEEN CLIMATOLOGIES OF CLOUD PARAMETERS DERIVED FROM SATELLITES AND FROM ATMOSPHERIC GENERAL CIRCULATION MODELS

NASA HQ EE84-736 (1)
1-16-84

CLOUD-CLIMATE PROCESSES RESEARCH

ISCCP

FIRE



GLOBAL SCALE: LARGE SCALE CLOUD RADIATIVE PROPERTIES

REGIONAL SCALE: COUPLING BETWEEN CLOUDS AND RADIATIVE-DYNAMICAL-HYDROLOGICAL PROCESSES

NASA HQ FE83 3276 (3)
8 24 83

Why is FIRE needed?

To improve the way clouds are parameterized in climate models

- o Inadequate knowledge of cloud formation, maintenance and dissipation
- o Lack of quantitative observation of physical processes affecting clouds and cloud/feedback to influence the atmosphere and surface

The Elements of FIRE

- o Validate the cloudiness and radiation parameterizations in climate models
- o Characterize the properties and determine the physical processes governing MBL clouds
- o Determine extent, radiation characteristics and processes that maintain cirrus
- o Derive statistics of cloud/physical radiative properties
- o Assemble data sets that facilitate independent study of the above

Validation of cloudiness and radiation parameterizations in climate models

- Identify biases in computed radiation for given cloud parameters
- Determine inadequacies in model prediction of cloud parameters
- Develop high resolution one dimensional radiation column model with aid of multi-view, multispectral satellite data
- One dimensional model to evaluate GCM radiation code
- Test ability of models to compute radiances for clear sky and varying complexities of cloud fields
- Validate prediction of cloud fields given synoptic scale distributions of temperature, humidity and vertical velocity

Program for
Marine Boundary Layer Clouds

- Satellite data – statistical characterization
- Surface-based observations to characterize thermodynamic structure of clouds
- Intensive field experiments to study physical processes that drive the clouds

FIRE: MARINE STATISTICAL SURVEY AND STRATUS/STRATOCUMULUS PROCESS STUDY

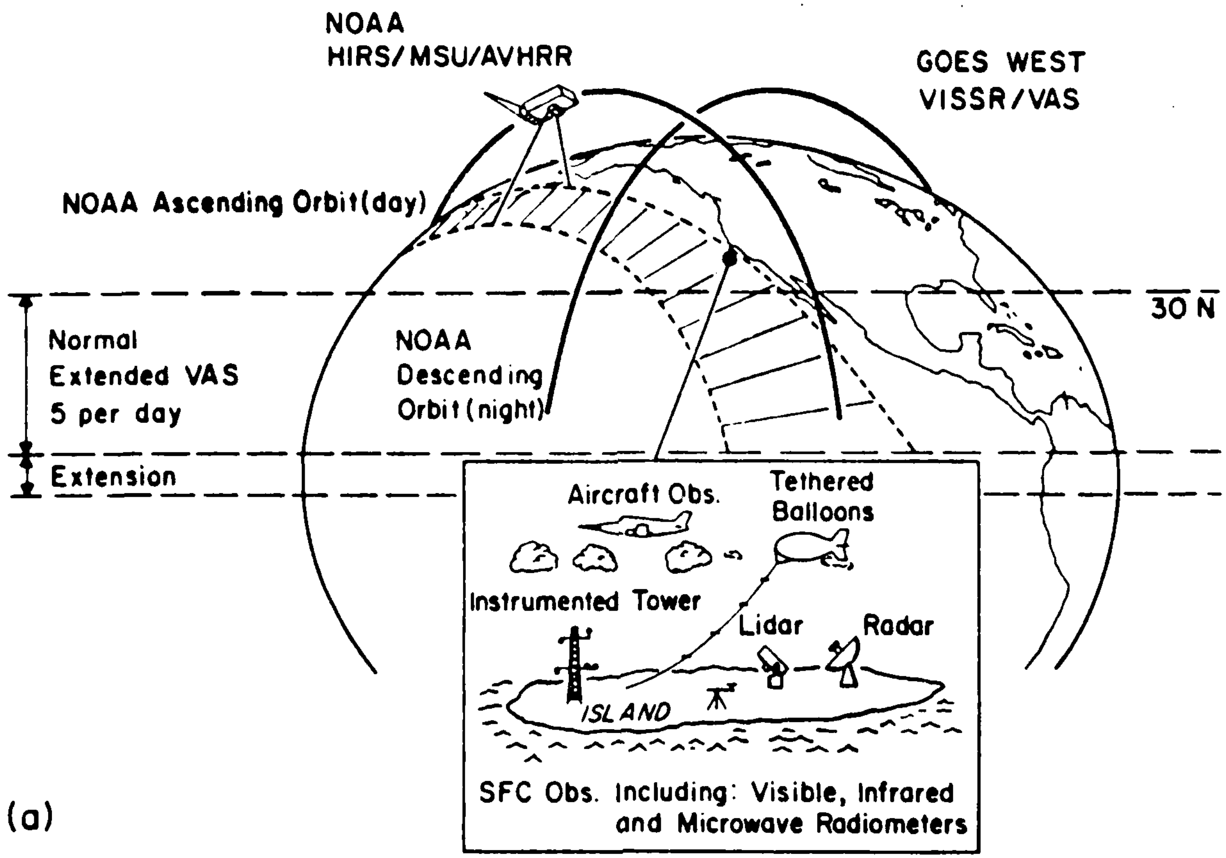


Figure 1.1 FIRE observing system. a) Schematic illustration of observing system for statistical survey of maritime clouds and for marine stratus/stratocumulus field experiment. Note that for these studies FIRE requires observations from both GOES satellites. Only the view from GOES West is shown.

Program for Cirrus Clouds

Model Study:

- o Processes maintaining cirrus against dissipation by ice crystal fallout

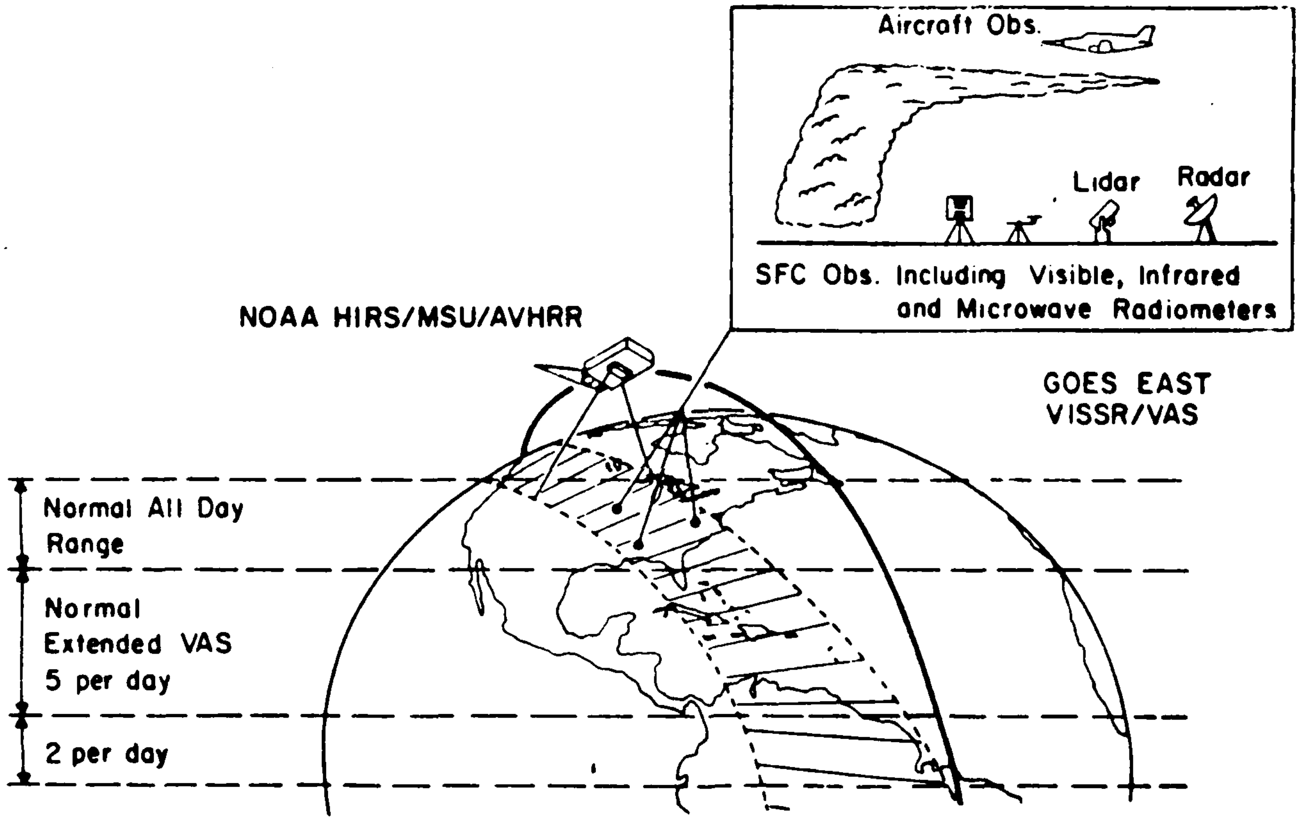
Field Study[1]:

- o Ground truth for validation of satellite radiation data
- o Data for phenomenological studies
- o Provide measurements for intercomparison with radiation calculations
- o Provide initialization and verification data sets for testing models

[1] Sites – Upper midwestern and south central coastal sections of U. S.

23

FIRE: CONTINENTAL STATISTICAL SURVEY AND CIRRUS PROCESS STUDY

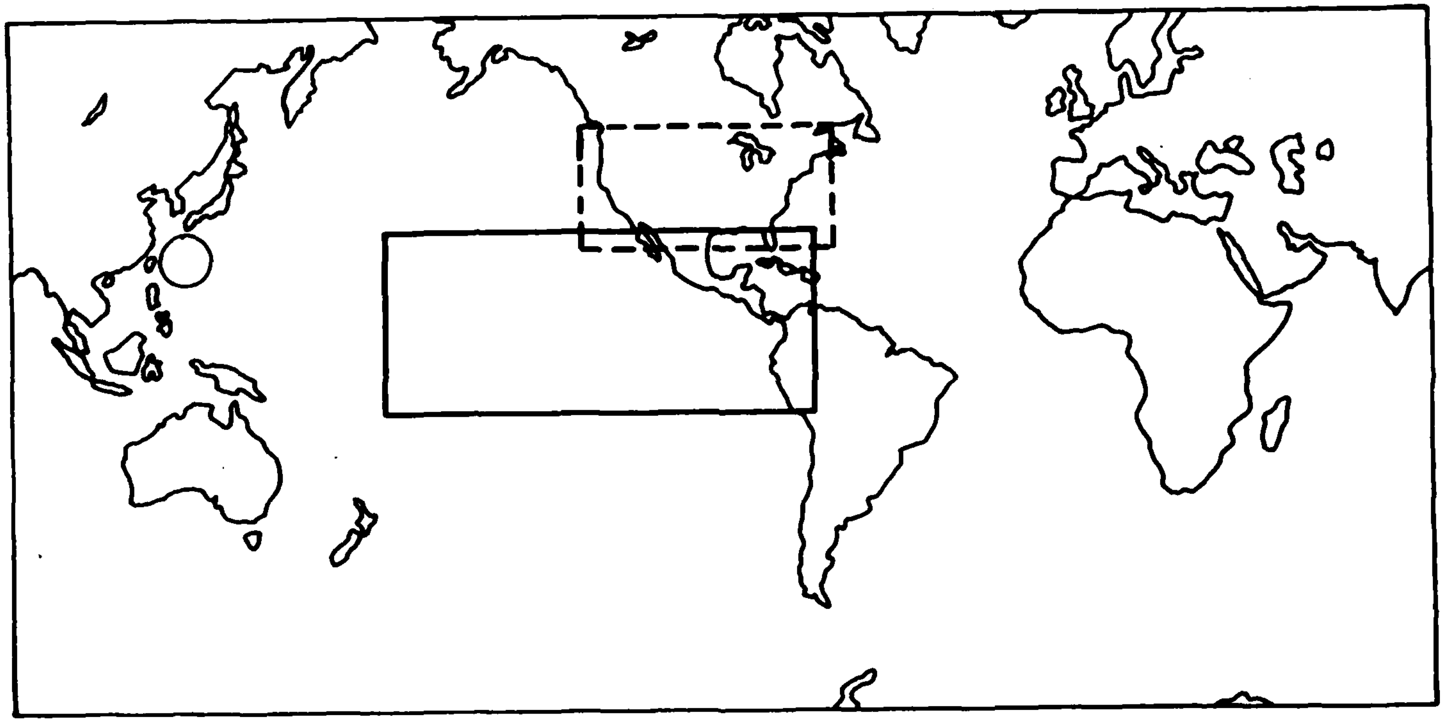


(b)

Figure 1.1 FIRE observing systems. b) Schematic illustration of observing system for statistical survey of continental clouds and for cirrus field experiment. Note that for these studies FIRE requires observations from both GOES satellites. Only the view from GOES East is shown.

INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT

REGIONAL EXPERIMENTS



CONTINENTAL U.S.A.

NORTHWEST PACIFIC

EL NINO/SO. OSCILLATION REGION

NASA HQ EE84-699 (1)
1-12-84

Statistical Studies

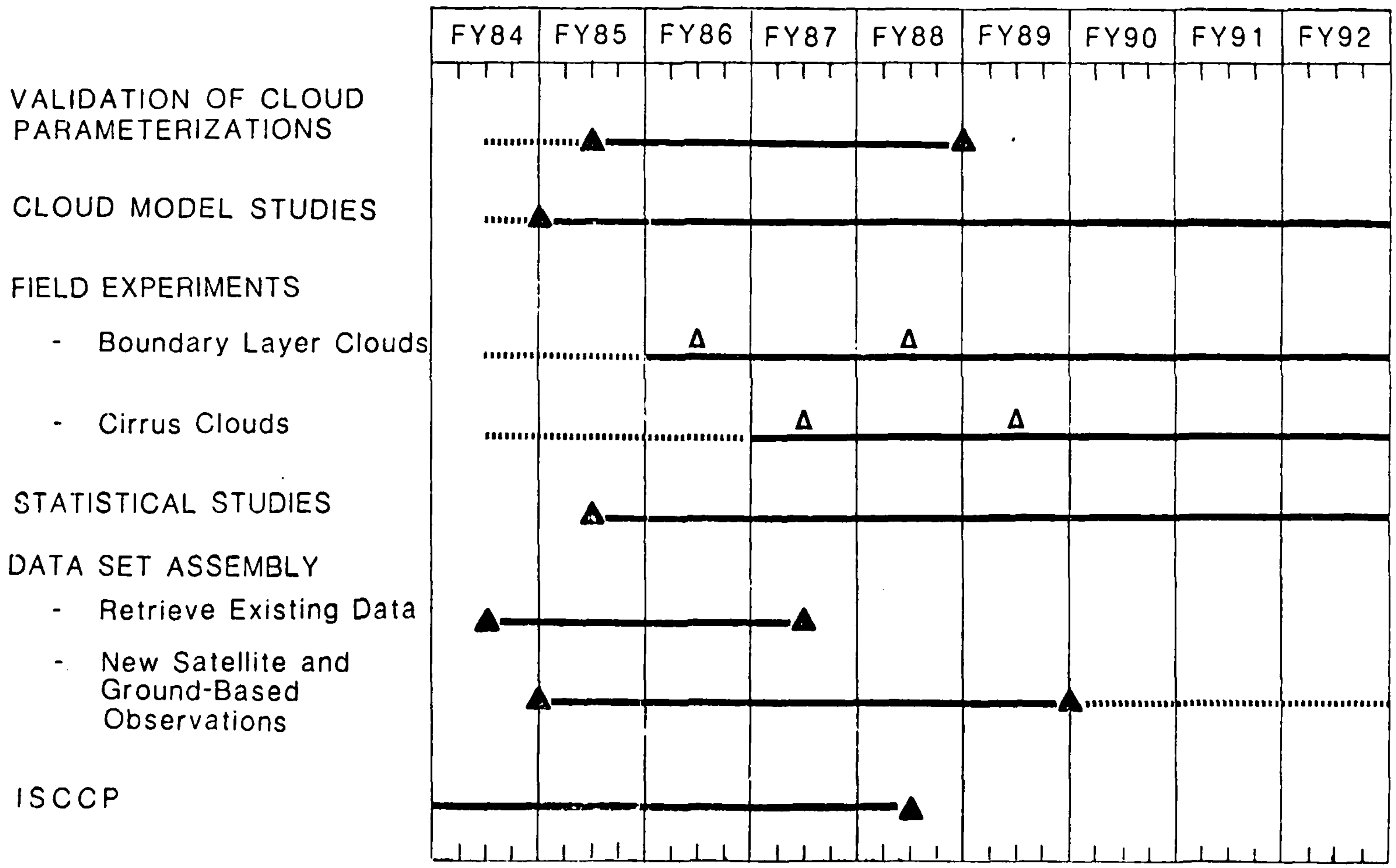
- Multiple samples – 10 categories
- Simultaneous data – overlap of GOES East and West
- 3 week periods each season
- Occasional simultaneous GOES to sample diurnal cycle

Data Collection

- o Selected case study data collected in one central facility
- o Entire set of raw data saved in individual archives for post-FIRE research
- o Data from several sources assembled onto one or more computer compatible tapes

Table 4.3.1

Schedule



Notes on the Viewgraphs

2 - The establishment of a global cloud climatology was the first sanctioned program under the World Climate Research Program.

3 - The reduced resolution radiances are being saved so that the cloud climatology can be recomputed if a significantly better algorithm is found.

5 - INSAT data will not be available from July 1, 1983 through December 31, 1984. NOAA 7 & 8 polar orbiter data will attempt to fill this gap. Beginning January 1, 1985, limited lower resolution INSAT data will become available.

6 - NOAA/NESDIS provides the correlative data on surface and atmospheric properties required by the GPC for the production of the cloud data sets.

7 - Canada actually became the GOES-E SPC in June, 1984.

9 & 10 - Upper left panel is a view of a smaller portion of the region than shown in the lower panels. The region of interest is off the northwest coast of South America plus some of South America.

21 - San Nicholas Island has been proposed as a site for the MBL field phase. The Department of the Navy has been cooperating with us on this, particularly NRL.

25 - Categories are for example cirrus alone, stratus alone, double layers, broken clouds, etc.

27 - Field experiments are for approximately a 3 week period in fiscal years separated by a 1 year gap for the purpose of giving time for analysis and making changes for the second field phase.

NOTE: FIRE is being supported by the NSF, NASA, NOAA, DOE, and to a limited extent by the DOD. More DOD support is encouraged (participation by individuals and funding).

MULTI-YEAR GLOBAL CLOUD DATA SET FROM NIMBUS-7 SATELLITE

P. Hwang
NASA/GSFS

L. Stowe
NOAA/NESDIS

P.K. Bhartia
SASC

MULTI-YEAR GLOBAL CLOUD DATA SET
FROM NIMBUS-7 SATELLITE

P. HWANG, NASA/GSFC (301) 344-9137

L. STOWE, NOAA/NESDIA (301) 763-4290

P. K. BHARTIA, SASC (301) 699-6111

OUTLINE

- OBJECTIVES
- REQUIRED INPUT & ALGORITHM
- VALIDATION
  - AIR FORCE TEMPERATURE
  - BCLE (THIR ONLY) & NCLE (THIR & TOMS)

OBJECTIVES

- SUPPORT NIMBUS-7 ERB AND SBUV/TOMS EXPERIMENTS
- INTERCOMPARE WITH ISCCP'S DATA TO FURTHER UNDERSTAND SATELLITE CLOUD MAPPING PROBLEM
- EXTEND ISCCP'S CLOUD DATA BASE 5 YEARS FORWARD

CLOUD RETRIEVAL FROM NIMBUS-7 SATELLITE DATA SETS

PRIMARY DATA BASE

- SURFACE TEMPERATURE
  - GLOBAL, EVERY THREE HOURS
- 11.5 MICRON RADIANCE
  - GLOBAL, TWICE A DAY
- ULTRAVIOLET REFLECTIVITY (.36 - .38μ)
  - GLOBAL, ONCE A DAY
- SNOW/ICE MAPS
  - GLOBAL, DAILY

SUPPORTING DATA BASE

- CLIMATOLOGICAL TEMPERATURE
- LOWER LEVEL (0 TO 2 KM) LAPSE RATE
- UPPER LEVEL (ABOVE 2 KM) LAPSE RATE
- TERRAIN HEIGHT
- LAND/WATER PERCENTAGES

COVERAGE: GLOBAL
RESOLUTION: 160 KM x 160 KM
FREQUENCY: MONTHLY AVERAGE

SURFACE TEMPERATURE DATA BASE

SOURCE:	AIR FORCE 3D-NEPHANALYSIS
RESOLUTION:	25 KM AT EQUATOR 50 KM AT POLE
FREQUENCY:	EVERY THREE HOURS
DATA PERIOD:	STARTING APRIL 1979
INFORMATION:	SHELTER TEMPERATURE OVER LAND SKIN TEMPERATURE OVER WATER
PROBLEMS:	INCORRECT TEMPERATURES OVER ANTARCTICA

11.5 MICRON RADIANCE DATA SET

SOURCE:	TEMPERATURE HUMIDITY INFRARED RADIOMETER (THIR)
CHANNEL:	11.5 MICRON 6.7 MICRON (NOT USED)
COVERAGE:	GLOBAL, APPROX. LOCAL NOON AND MIDNIGHT
RESOLUTION:	6.7 KM x 6.7 KM AT NADIR 12 KM x 24 KM OFF-NADIR
DATA PERIOD:	NOV 78 — CONTINUING (USED STARTING APRIL 1979)

CLOUD RETRIEVAL FROM INFRARED ONLY

STEPS:

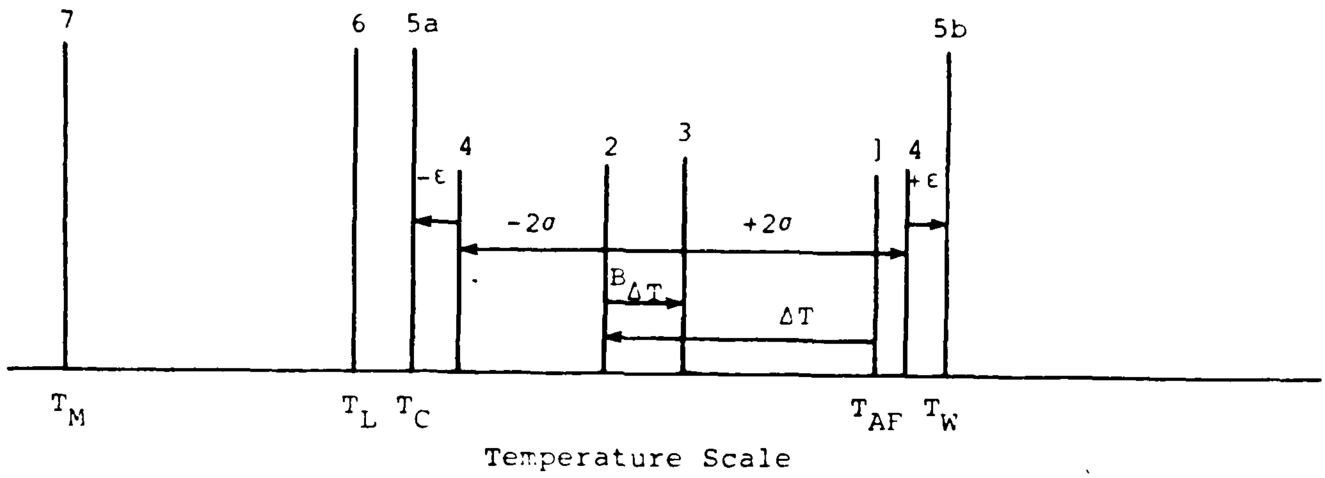
1) ATTENUATION CORRECTION
   - POLYNOMINAL IN SURFACE TEMP & SATELLITE ZENITH ANGLE
   - BIAS ADJUSTMENT

2) ESTIMATION OF UNCERTAINTY IN CORRECTED TEMPERATURE
   - 2^{o} K ERROR IN ATTENUATION CORRN
   - TEMPERATURE INHOMOGENEITY ESTIMATED FROM AIR FORCE DATA

3) DETERMINATION OF CLOUD/NO CLOUD THRESHOLD

4) ESTIMATION OF MID & HIGH CLOUD THRESHOLDS

THRESHOLDS FOR IMPROVED NIMBUS-7 THIR CLOUD ANALYSIS (BLCE)



(1) SURFACE TEMPERATURE FROM AIR FORCE ANALYSIS

(2) ADJUSTMENT FOR ATMOSPHERIC ATTENUATION (2-8C)

(3) BIAS IN ATTENUATION ADJUSTMENT (2C)

(4) TWICE STANDARD DEVIATION OF VARIANCE DUE TO HUMIDITY AND HORIZONTAL

(5) ADJUSTMENT FOR PARTIALLY FILLED FIELDS OF VIEW (2C)

(5A) CLOUD/NO CLOUD THRESHOLD

(5B) CLOUD/NO CLOUD THRESHOLD WHEN CLIMATOLOGICAL INVERSION PRESENT

(6) LOW/MID CLOUD THRESHOLD

(7) MID/HIGH CLOUD THRESHOLD

ULTRAVIOLET REFLECTIVITY DATA SET

SOURCE:	TOTAL OZONE MAPPING SPECTROMETER (TOMS)
CHANNELS:	4 FOR TOTAL OZONE (.31 - .34μ) - NOT USED 2 FOR REFLECTIVITY (.36 & .38μ)
COVERAGE:	SUNLIT PORTION OF GLOBE AT APPROX LOCAL NOON
RESOLUTION:	50 KM AT NADIR 150 KM OFF-NADIR
DATA PERIOD:	SAME AS THIR

COMPUTATION OF ULTRAVIOLET REFLECTIVITY

GEOMETRICAL ALBEDO = F(θ_0, θ, ϕ, P_T, β, R)

WHERE:

θ_0 = SOLAR ZENITH ANGLE

θ = SATELLITE ZENITH ANGLE

ϕ = AZIMUTH ANGLE

P_T = TERRAIN PRESSURE

β = RAYLEIGH SCATTERING COEFF.

R = REFLECTIVITY

APPROXIMATION MADE:

o SURFACE ASSUMED LAMBERTIAN FOR ATMOSPHERIC SCATTERING COMPUTATION

PROPERTIES OF TOMS DERIVED REFLECTIVITY

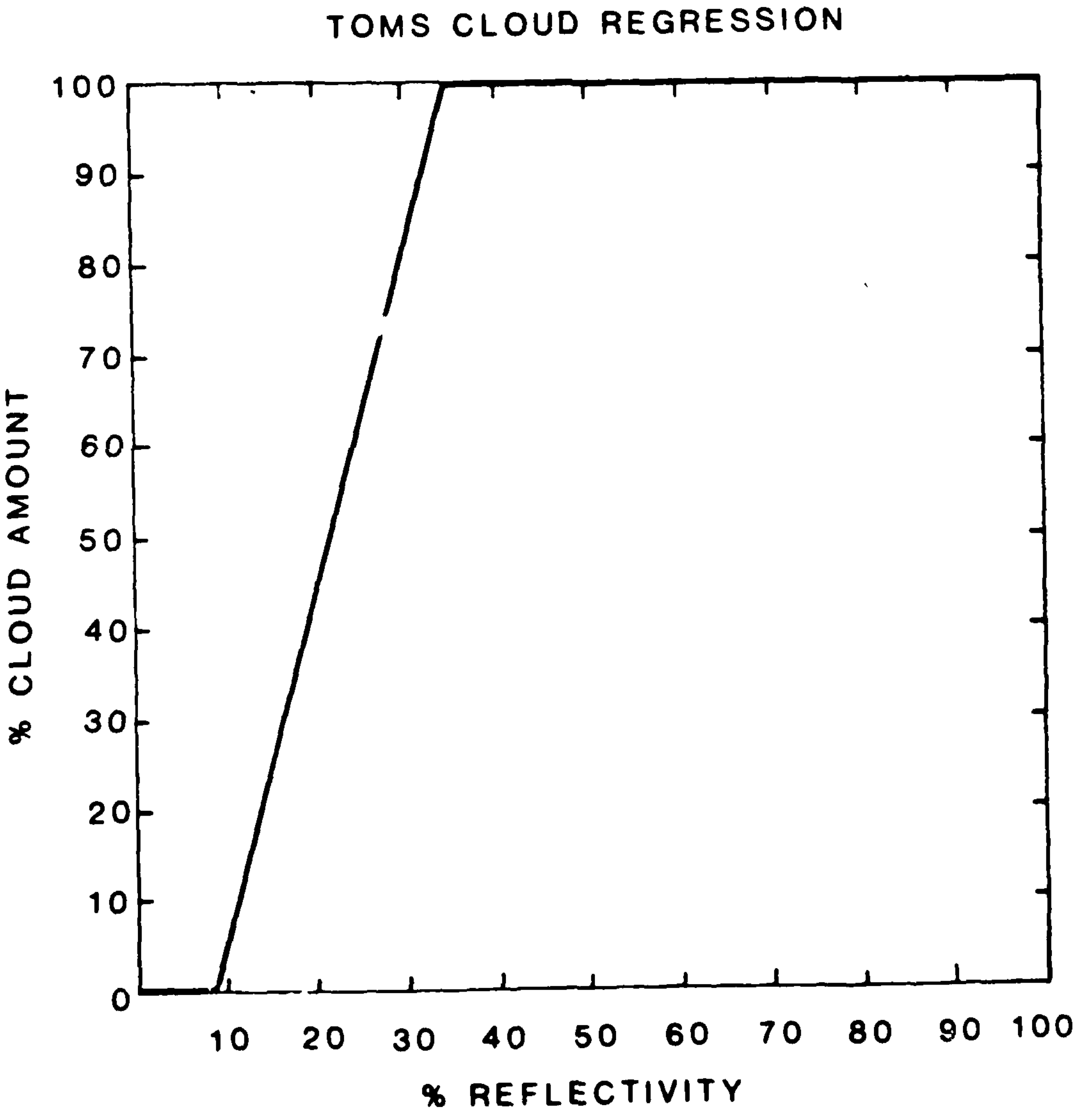
SIMILARITIES TO VISIBLE

- CLOUDS/WATER CONTRAST AS HIGH AS IN VISIBLE
- CLOUD/SNOW/ICE CONTRAST AS POOR AS IN VISIBLE

DISSIMILARITIES WITH VISIBLE

- NO SIGNIFICANT LAND/WATER DIFFERENCE IN REFLECTIVITY
  - EVEN THE DESERTS
- SOLAR GLINT EFFECTS ARE WEAKER
- NO SIGNIFICANT ATMOSPHERIC ABSORPTION
- MUCH BETTER ABSOLUTE CALIBRATION

2-10 6a



TOMS CLOUD REGRESSION
100
90
80
70
60
50
40
30
20
10
0
% CLOUD AMOUNT
10 20 30 40 50 60 70 80 90 100
% REFLECTIVITY

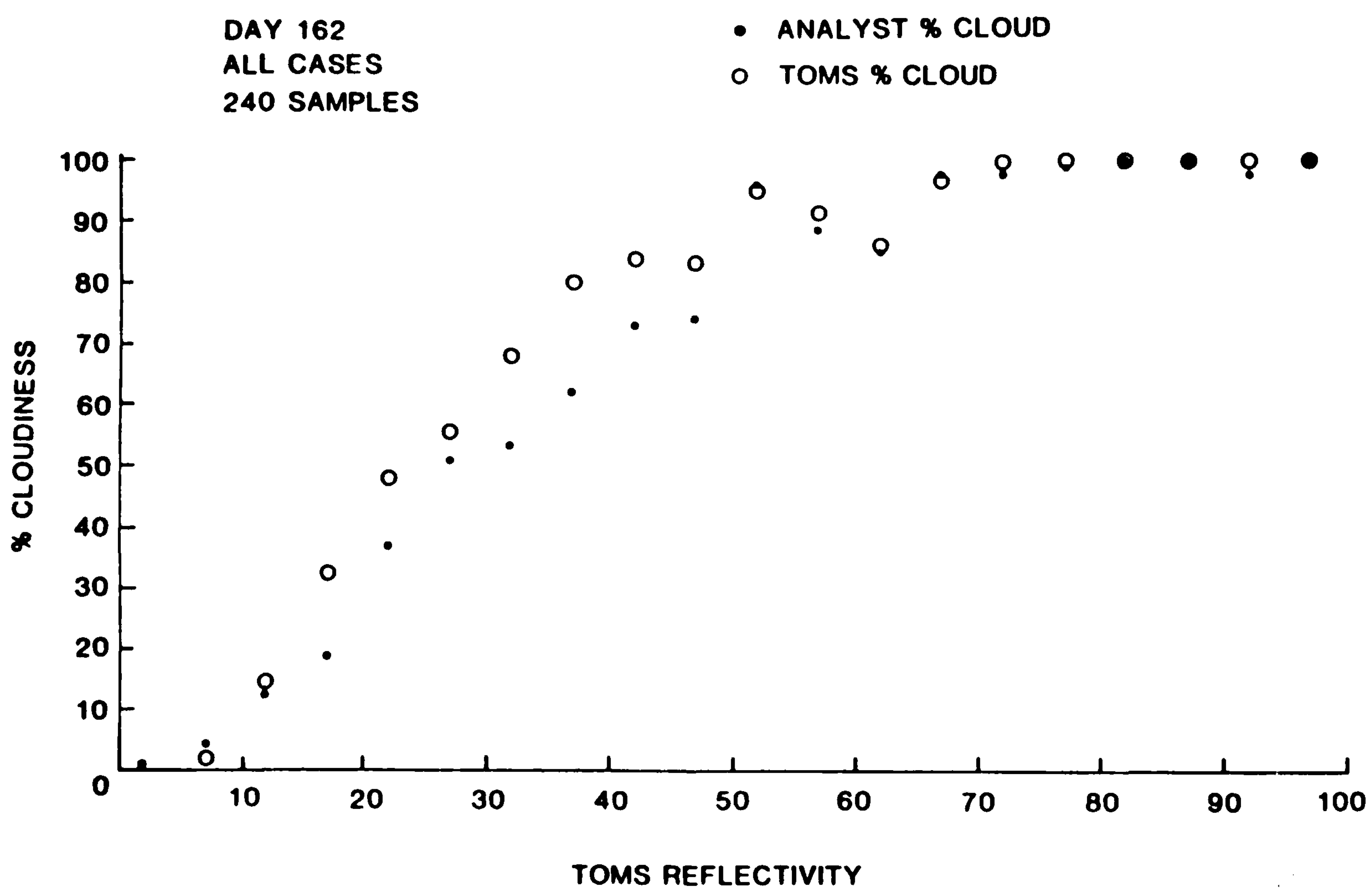

DAY 162
ALL CASES
240 SAMPLES
ANALYST % CLOUD
TOMS % CLOUD
% CLOUDINESS
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
TOMS REFLECTIVITY

Figure 3

COMPARISON OF THIR & TOMS CLOUD RETRIEVAL ERRORS

THIR	TOMS
LESS NOISY	MORE NOISY
CLOUDS WARMER THAN THRESHOLD UNDETECTABLE	ALL CLOUDS DETECTABLE, EXCEPT THOSE THAT ARE VERY THIN
MAY OVERESTIMATE COLD SUB-PIXEL CLOUDS (CIRRUS), UNDERESTIMATE WARM SUB-PIXEL CLOUDS (CUMULUS)	MAY UNDERESTIMATE THIN CLOUDS (CIRRUS), OVERESTIMATE THICK CLOUDS (CUMULONIMBUS)
MAY UNDERESTIMATE THIN CLOUDS OVER LAND WITH HIGH SKIN TEMPERATURE (DESERTS)	WILL DETECT, BUY MAY UNDERESTIMATE
DEPENDENT ON THE ACCURACY OF AIR FORCE TEMPERATURE	NOT DEPENDENT ON EXTERNAL INFO, EXCEPT FOR SNOW/ICE
STRONG ATMOSPHERIC ATTENUATION - HARD TO ESTIMATE ACCURATELY	STRONG SCATTERING EFFECTS - BUT WELL ESTIMATED

COMBINING THIR WITH TOMS

RECOMMENDED CLOUD AMOUNT = THIR * (1-W) + TOMS * W

WHERE:

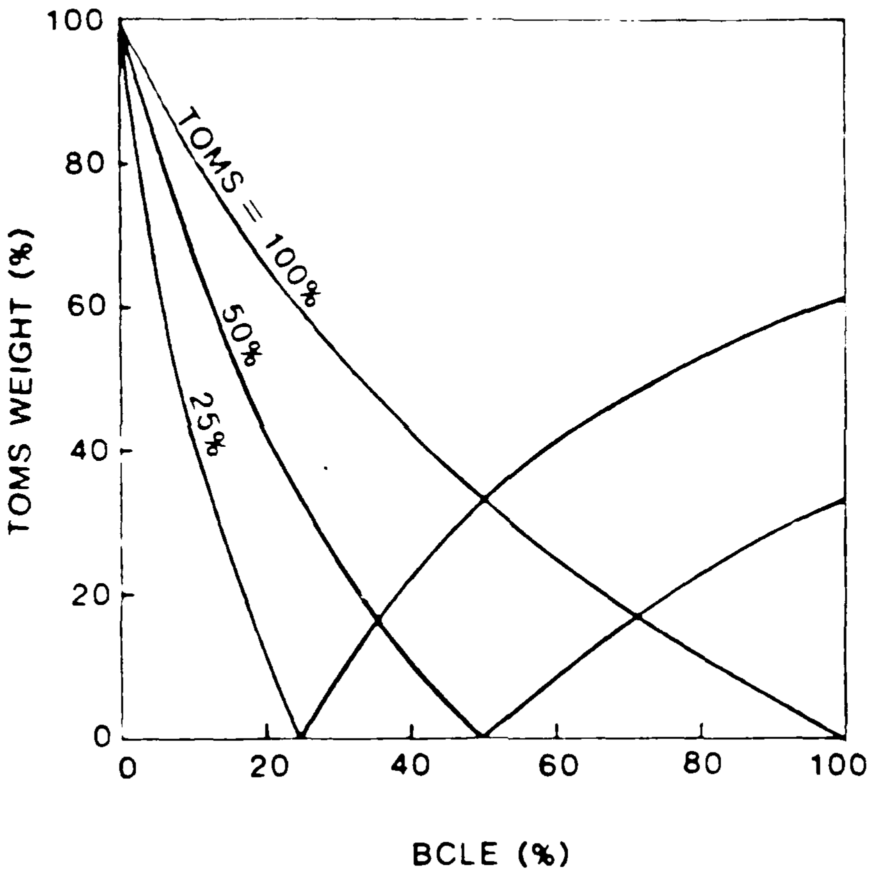
$$W = W_1 W_2$$

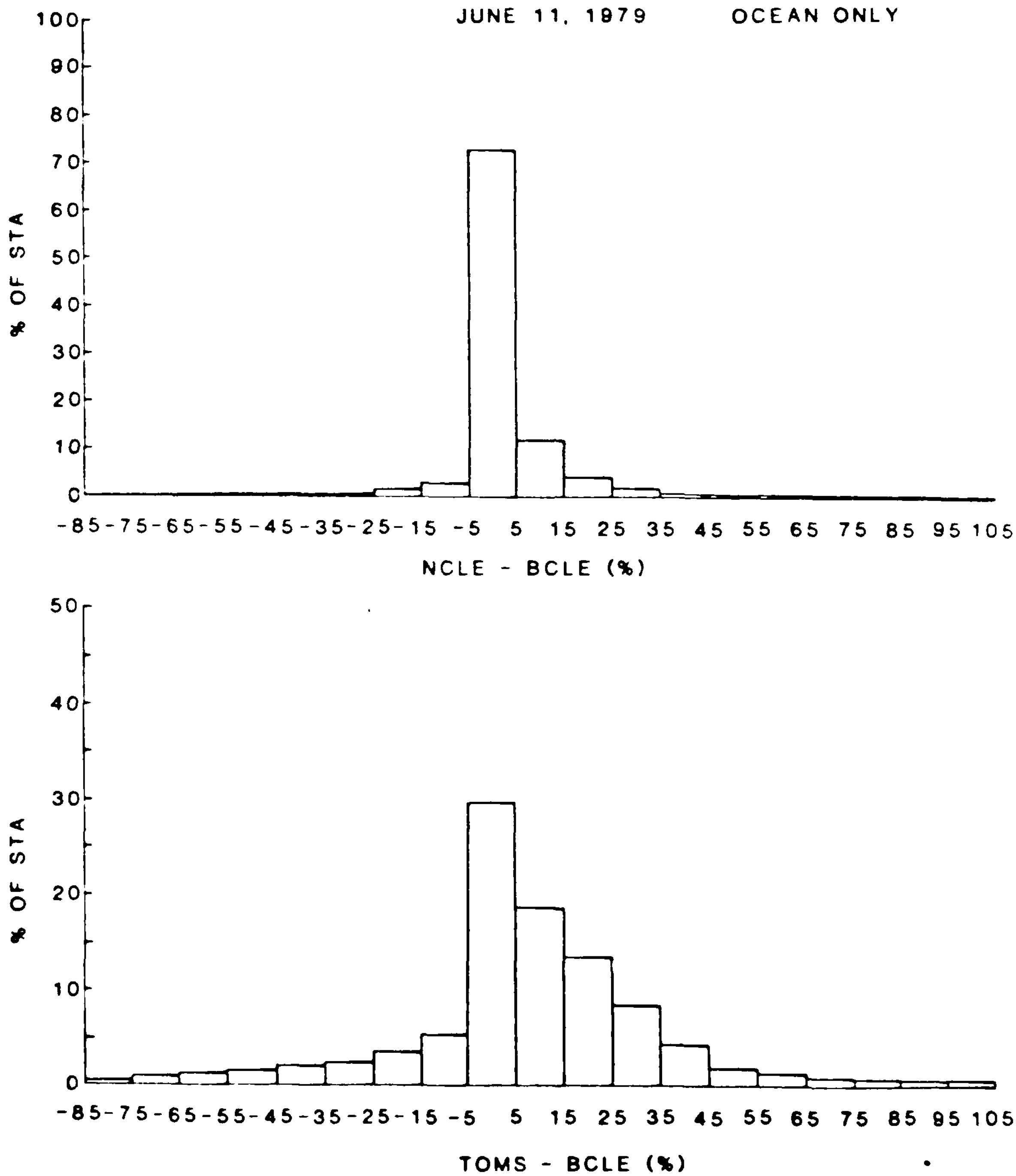
$W_1 = \frac{N}{1+N}$ N = NO. OF TOMS SAMPLE IN A SUB-PIXEL AREA

$W_2 = \frac{|THIR - TOMS|}{THIR + TOMS}$

- o GIVES LESS WEIGHT TO TOMS WHEN THIR AND TOMS ARE IN GOOD AGREEMENT, AND CLOUDS ARE PRESENT

WEIGHTING SCHEME FOR COMBINING THIR & TOMS




JUNE 11, 1979
OCEAN ONLY
% OF STA
0
10
20
30
40
50
60
70
80
90
100
-85 -75 -65 -55 -45 -35 -25 -15 -5 5 15 25 35 45 55 65 75 85 95 105
NCLE - BCLE (%)
% OF STA
0
10
20
30
40
50
-85 -75 -65 -55 -45 -35 -25 -15 -5 5 15 25 35 45 55 65 75 85 95 105
TOMS - BCLE (%)

CLOUD CLASSIFICATION

FIVE TYPES: (BASED STRICTLY ON RADIATIVE TEMP)

- LOW
  - TOP BELOW 2 KM
- MID
  - BETWEEN LOW & HIGH
- HIGH
  - ABOVE 7 KM AT EQUATOR
  - ABOVE 4 KM AT POLES
- WARM
  - DURING TEMP INVERSIONS ONLY
- CIRRUS
  - MID + HIGH AMOUNT WHEN THIR SEES CLOUDS BUT TOMS HAS LOW REFLECTIVITY
  - WILL NOT BE IDENTIFIED IN PRESENCE OF OTHER MID OR HIGH CLOUDS

AIR FORCE SURFACE TEMPERATURE ANALYSIS

SOURCE OF DATA

LAND - CONVENTIONAL SHELTER TEMPERATURE REPORTS FROM NMC AND AIR WEATHER SERVICE RECEIVED EVERY THREE HOURS.

OCEAN - SEA SURFACE TEMPERATURE REPORTS DERIVED FROM MICROWAVE SATELLITE AND SHIP REPORTS RECEIVED EVERY SIX HOURS FROM NAVY FLEET NUMERICAL WEATHER CENTRAL.

ANALYSIS PROCEDURES

* USE FIVE LAYER MODEL ANALYSIS ON WHOLE MESH GRID (320 KM).

* INTERPOLATE TO HALF MESH GRID (160 KM) AND EXTRAPOLATE FROM THE GRADIENT LEVEL (60 MB ABOVE TERRAIN) TO SURFACE USING CLIMATOLOGICAL LAPSE RATES.

* APPLY DIURNAL TEMPERATURE CORRECTIONS DERIVED EMPIRICALLY.

* INCORPORATE MOST CURRENT SHELTER TEMPERATURES INTO THE ANALYSIS USING MODIFIED BARNES TECHNIQUE.

* INCORPORATE NAVY'S SEA SURFACE TEMPERATURE ANALYSIS ON HALF MESH GRID.

* INCORPORATE MOST CURRENT SEA SURFACE TEMPERATURES AND INTERPOLATE THE GLOBAL FIELD TO THE EIGHTH MESH GRID (40 KM).

* ONCE AGAIN APPLY ALL CURRENT LAND SHELTER TEMPERATURES BUT TO THE EIGHTH MESH FIELD.

* DO THIS EVERY THREE HOURS AND ARCHIVE AT NATIONAL CLIMATE CENTER, ASHVILLE, N.C. BEGINNING APRIL 1, 1979.

QUALITY OF ANALYSIS

NORTHERN HEMISPHERE

June 11, 1979

Area	Time	No. of Obs.	(A.F.-SFC) Mean Dif.	(A.F.-SFC) Std. Dev. of Diff.
44	00Z	64	-0.3	2.6
	12Z	64	0.0	2.7
19	00Z	51	-1.3	1.8
	12Z	51	-0.2	1.4
39	00Z	27	-0.7	3.1
	12Z	35	-0.6	2.0
21	00Z	46	-1.4	6.1
	12Z	45	-1.2	5.3

December 1, 1979

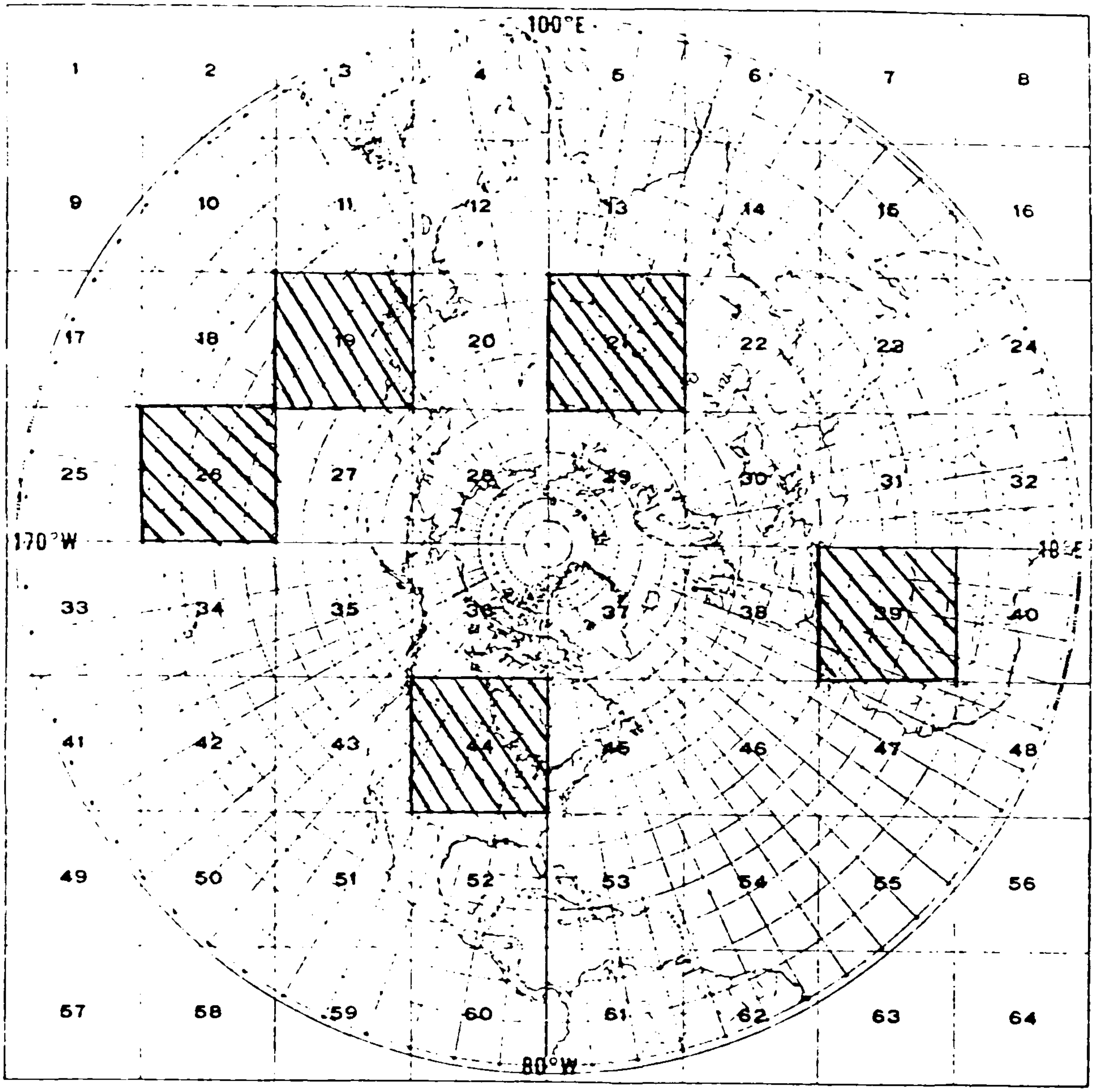
Area	Time	No. of Obs.	(A.F.-SFC) Mean Diff.	(A.F.-SFC) Std. Dev. of Diff.
44	00Z	61	-0.3	2.0
	12Z	53	0.1	2.3
19	00Z	17	0.4	1.6
	12Z	13	0.6	1.3
39	00Z	13	0.0	1.2
	12Z	26	-0.8	2.3
21	00Z	41	-0.4	2.3
	12Z	38	0.2	3.6

SOUTHERN HEMISPHERE

Differences were less than 5°C for June 11 and December 1, 1979 for both 00Z and 12Z throughout the southern hemisphere with the exception being in the High Terrain Regions of Antartica.

(June)	South Pole	Vostok (78S, 107E)
Air Force	-16°C	-13°C
Raob	-56°C	-74°C

3-3



NORTHERN HEMISPHERE

Figure 1. Northern Hemisphere 3DNEPH grid over a polar stereographic projection. Each square partition is a "3DNEPH Box". Corner boxes are not used.

34

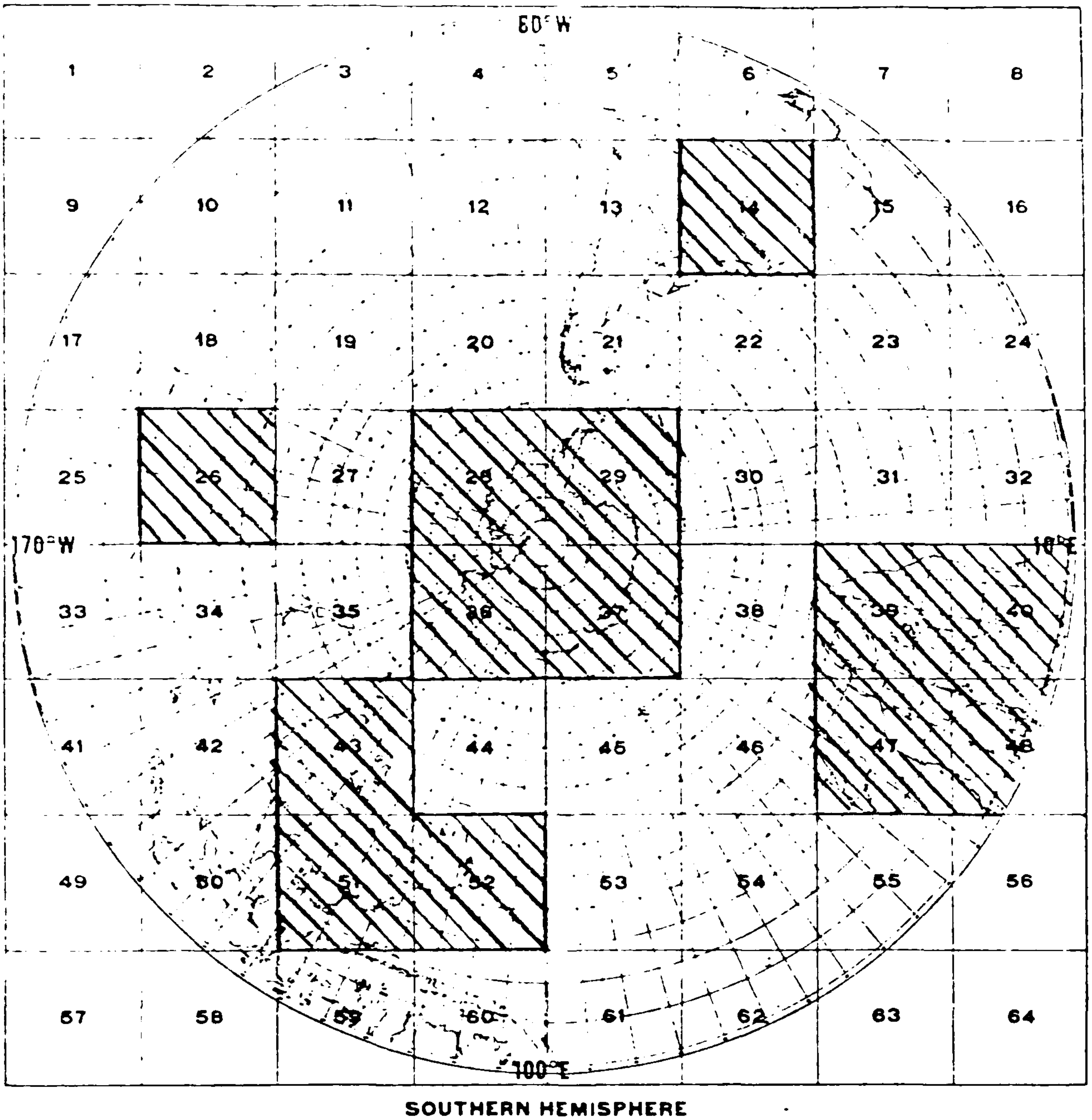


Figure 2. Southern Hemisphere 3DNEPH grid.

4

WATER 6-11-79 17Z

ALGORITHM	CLE	BCLE(4)	TOMS	NCLE(6)
CORRELATION COEFFICIENT	0.60	0.93	0.91	0.95
RMS DIFFERENCE	41	14	17	12
MEAN OF ALGORITHM (% CLOUD)	65	41	49	46
MEAN OF ANALYST (% CLOUD)	40	40	40	40
SAMPLE SIZE	96	96	90	96

WATER 12-3-79 17Z

ALGORITHM	CLE	BCLE(4)	TOMS	NCLE(6)
CORRELATION COEFFICIENT	0.83	0.94	0.91	0.94
RMS DIFFERENCE	16	10	13	9
MEAN OF ALGORITHM (% CLOUD)	81	78	81	78
MEAN OF ANALYST (% CLOUD)	79	79	79	79
SAMPLE SIZE	134	134	133	134

WATER 12-4-79 05Z

ALGORITHM	CLE	BCLE(4)	TOMS	NCLE(6)
CORRELATION COEFFICIENT	0.86	0.95		
RMS DIFFERENCE	19	11		
MEAN OF ALGORITHM (% CLOUD)	77	75		
MEAN OF ANALYST (% CLOUD)	71	71		
SAMPLE SIZE	143	143		

LAND 6-11-79 17Z

ALGORITHM	CLE	BCLE(4)	TOMS	NCLE(6)
CORRELATION COEFFICIENT	0.93	0.96	0.95	0.96
RMS DIFFERENCE	18	12	13	12
MEAN OF ALGORITHM (% CLOUD)	51	37	42	39
MEAN OF ANALYST (% CLOUD)	42	42	42	42
SAMPLE SIZE	68	68	68	68

LAND 12-3-79 17Z

ALGORITHM	CLE	BCLE(4)	TOMS	NCLE(6)
CORRELATION COEFFICIENT	0.62	0.67	0.85	0.66
RMS DIFFERENCE	38	39	22	39
MEAN OF ALGORITHM (% CLOUD)	34	25	44	28
MEAN OF ANALYST (% CLOUD)	51	51	53	51
SAMPLE SIZE	59	59	56	59

LAND 12-4-79 05Z

ALGORITHM	CLE	BCLE(4)	TOMS	NCLE(6)
CORRELATION COEFFICIENT	0.04	0.97		
RMS DIFFERENCE	63	11		
MEAN OF ALGORITHM (% CLOUD)	89	50		
MEAN OF ANALYST (% CLOUD)	50	50		
SAMPLE SIZE	38	38		

COASTAL 6-11-79 17Z

ALGORITHM	CLE	BCLE(4)	TOMS	NCLE(6)
CORRELATION COEFFICIENT	0.65	0.87	0.94	0.95
RMS DIFFERENCE	34	22	14	12
MEAN OF ALGORITHM (% CLOUD)	61	39	51	46
MEAN OF ANALYST (% CLOUD)	48	48	48	48
SAMPLE SIZE	79	79	79	79

COASTAL 12-3-79 17Z

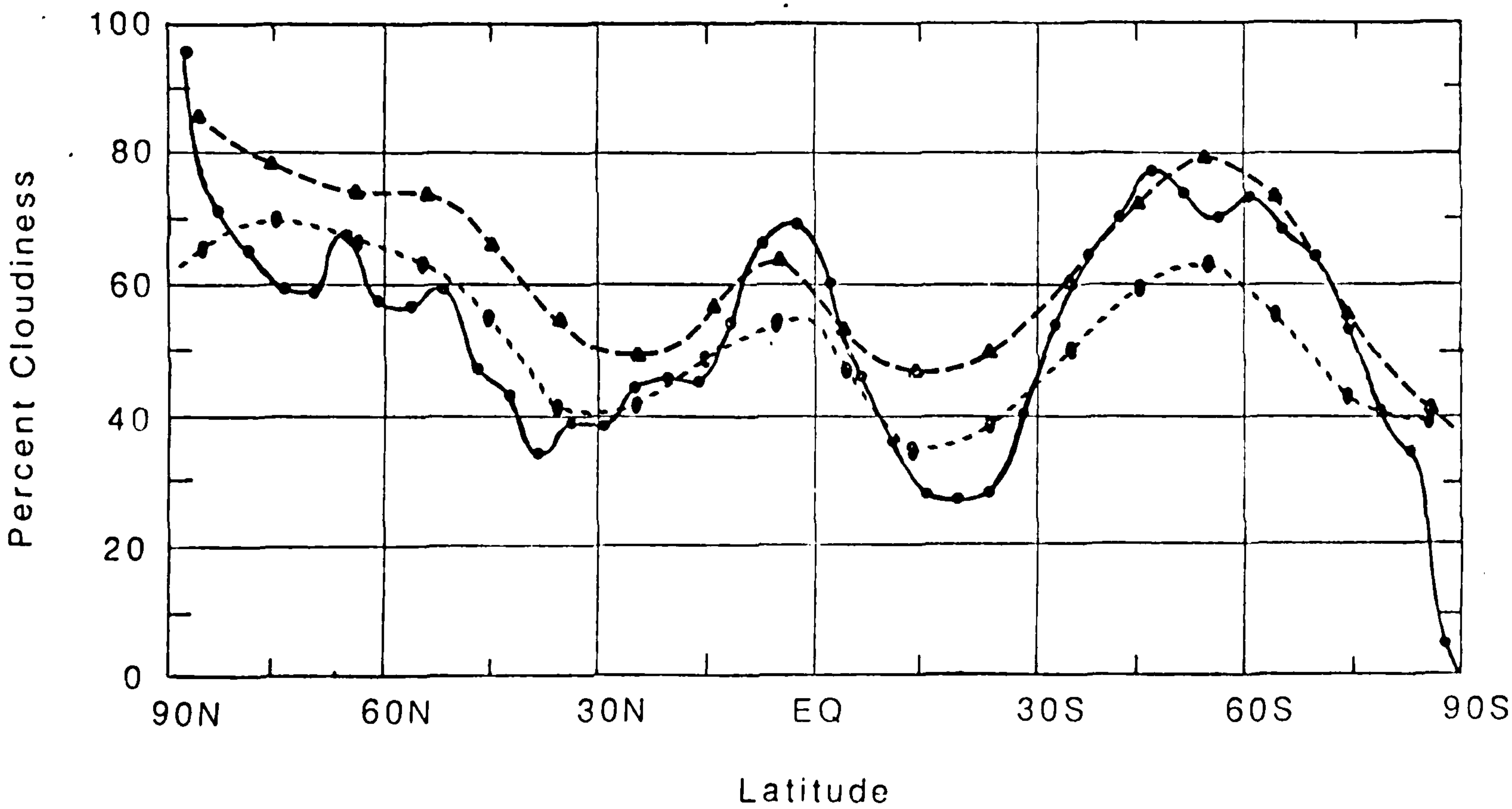
ALGORITHM	CLE	BCLE(4)	TOMS	NCLE(6)
CORRELATION COEFFICIENT	0.59	0.62	0.91	0.75
RMS DIFFERENCE	34	35	16	26
MEAN OF ALGORITHM (% CLOUD)	51	43	56	48
MEAN OF ANALYST (% CLOUD)	58	58	58	58
SAMPLE SIZE	104	104	103	104

COASTAL 12-4-79 05Z

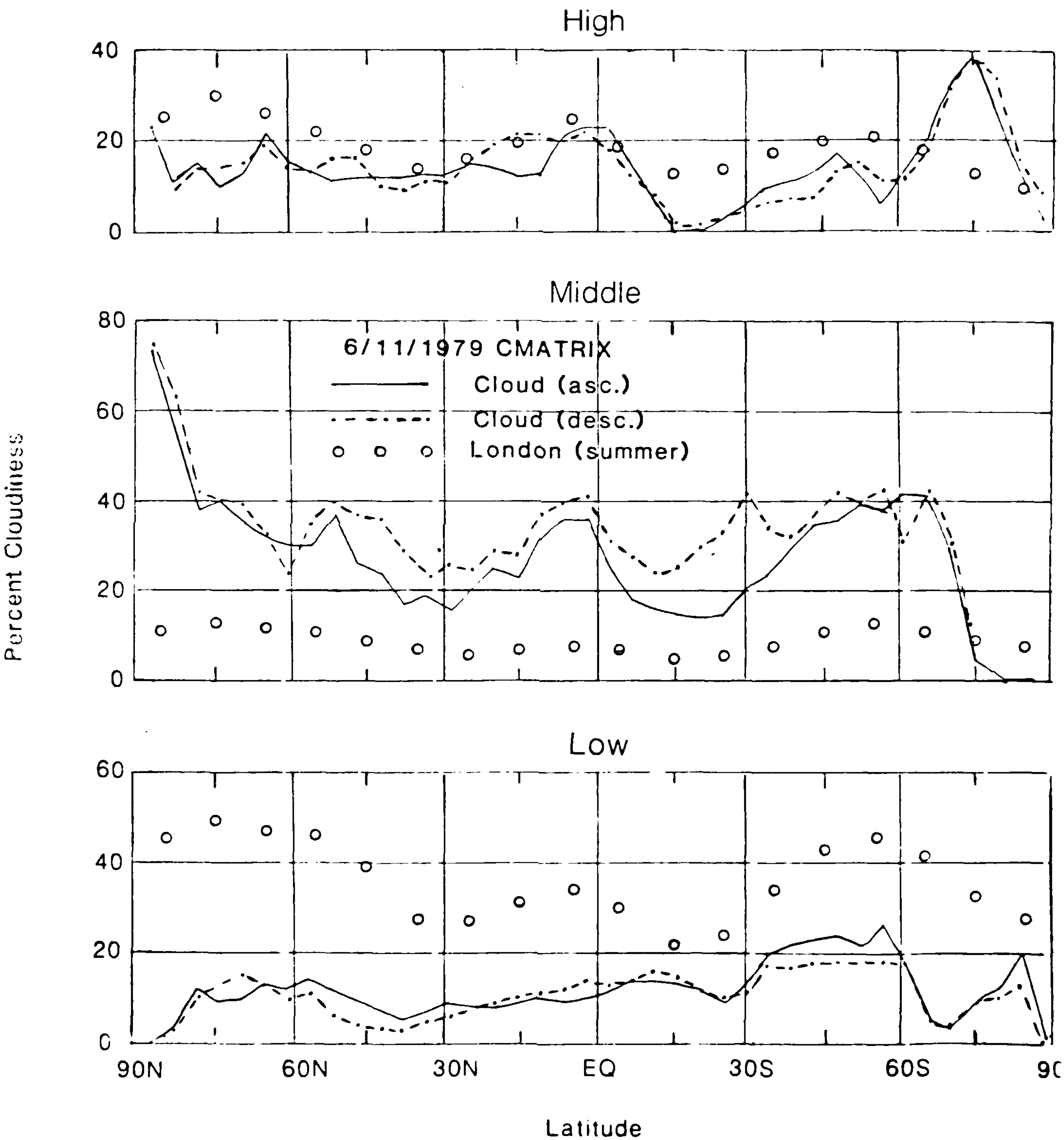
ALGORITHM	CLE	BCLE(4)	TOMS	NCLE(6)
CORRELATION COEFFICIENT	0.71	0.94		
RMS DIFFERENCE	39	14		
MEAN OF ALGORITHM (% CLOUD)	70	49		
MEAN OF ANALYST (% CLOUD)	45	45		
SAMPLE SIZE	93	93		

Zonal Average Cloud Cover

N H (%)	S H (%)	Global (%)	
52	48	50	London (1957) Summer
62	58	60	Berlyand et al. (1980) June
52	51	52	NIMBUS 7, 11 June 1979 (Ascending)



Zonal Average Cloud Cover



VIEWING ANGLE BIAS IN CLOUD CLIMATOLOGIES

J. Bunting
Air Force Geophysics Laboratory

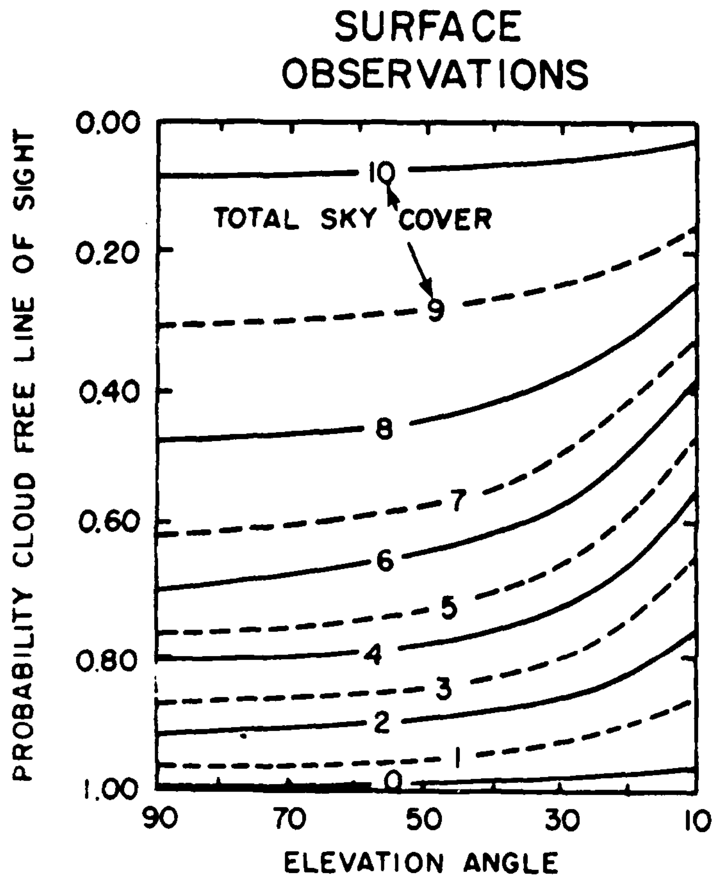
G. Gustafson
Systems and Applied Science Corporation

J. Arck
Air Force Geophysics Laboratory

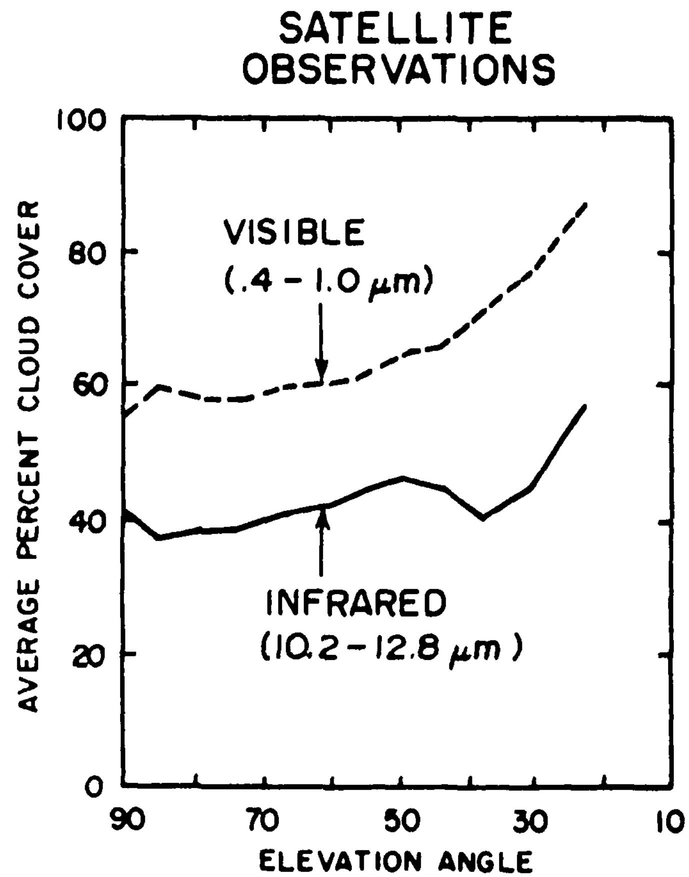
VIEWING ANGLE BIAS IN CLOUD CLIMATOLOGIES

BY: J. BUNTING, AFGL
G. GUSTAFSON, SASC
J. ARCK, AFGL

TO: TRI-SERVICE CLOUD MODELING WORKSHOP
27 JUNE 1984



SURFACE OBSERVATIONS
PROBABILITY CLOUD FREE LINE OF SIGHT
0.00
0.20
0.40
0.60
0.80
1.00
TOTAL SKY COVER
10
9
8
7
6
5
4
3
2
1
0
90
70
50
30
10
ELEVATION ANGLE



SATELLITE OBSERVATIONS
AVERAGE PERCENT CLOUD COVER
100
80
60
40
20
0
VISIBLE
(.4 - 1.0 μm)
INFRARED
(10.2 - 12.8 μm)
90
70
50
30
10
ELEVATION ANGLE

WHAT CHANGES WITH SATELLITE VIEWING ANGLE

PROBABILITY OF CFLOS

ATMOSPHERIC TRANSMISSION

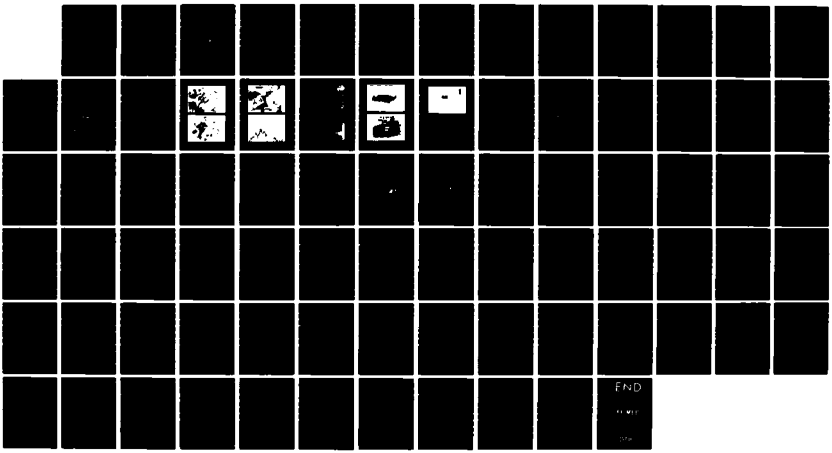
REFELECTIVITY, EMISSIVITY OF BACKGROUND

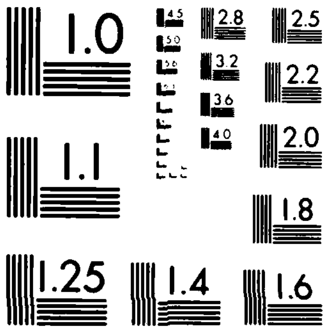
HORIZONTAL RESOLUTION OF SATELLITE DATA

AD-A152 735 PRESENTATIONS AT THE TRI-SERVICE CLOUD MODELING WORKSHOP (2ND) HELD AT TH..(U) INSTITUTE FOR DEFENSE ANALYSES ALEXANDRIA VA E BAUER AUG 84 IDA-M-9-VOL-1 IDA/HQ-84-28971 MDA903-84-C-0031

7/7

UNCLASSIFIED F/G 4/2 NL



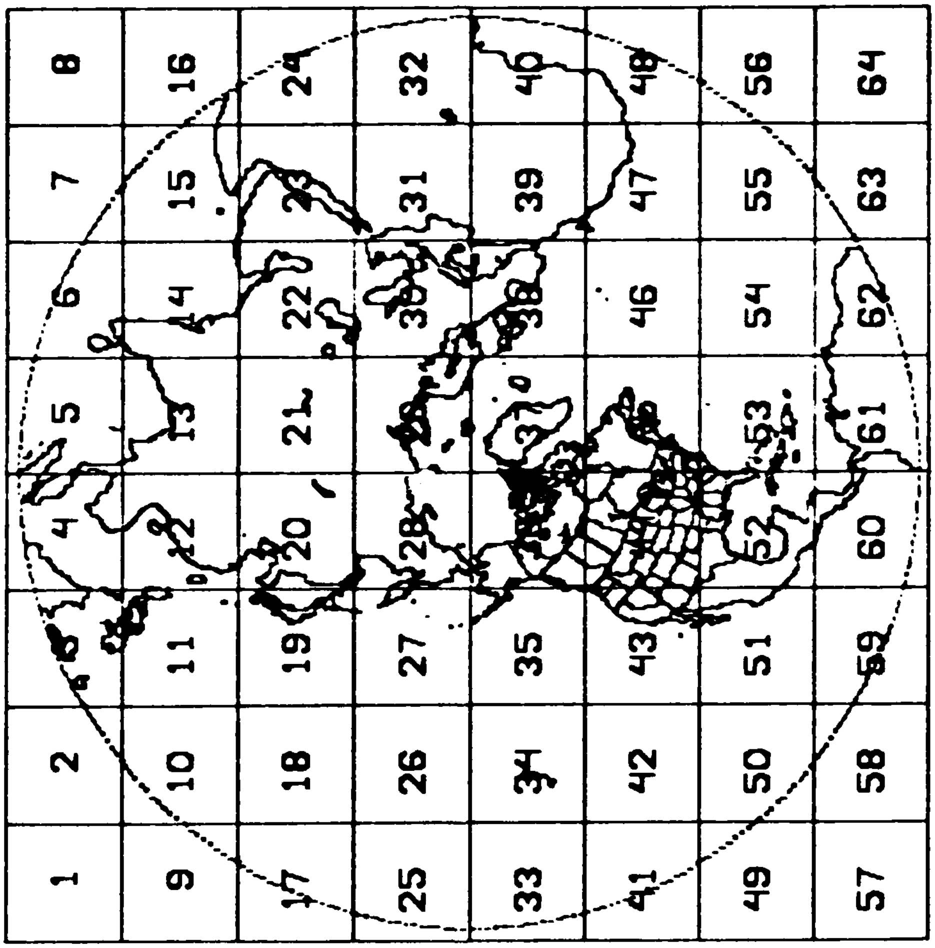


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

AFGL STUDIES ON VIEWING ANGLE BIAS

DMSP AND NOAA SATELLITE DATA FROM AFGWC SGDB

CLOUD COVER FROM AFGL R&DNEPH


1
2
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20
21
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43
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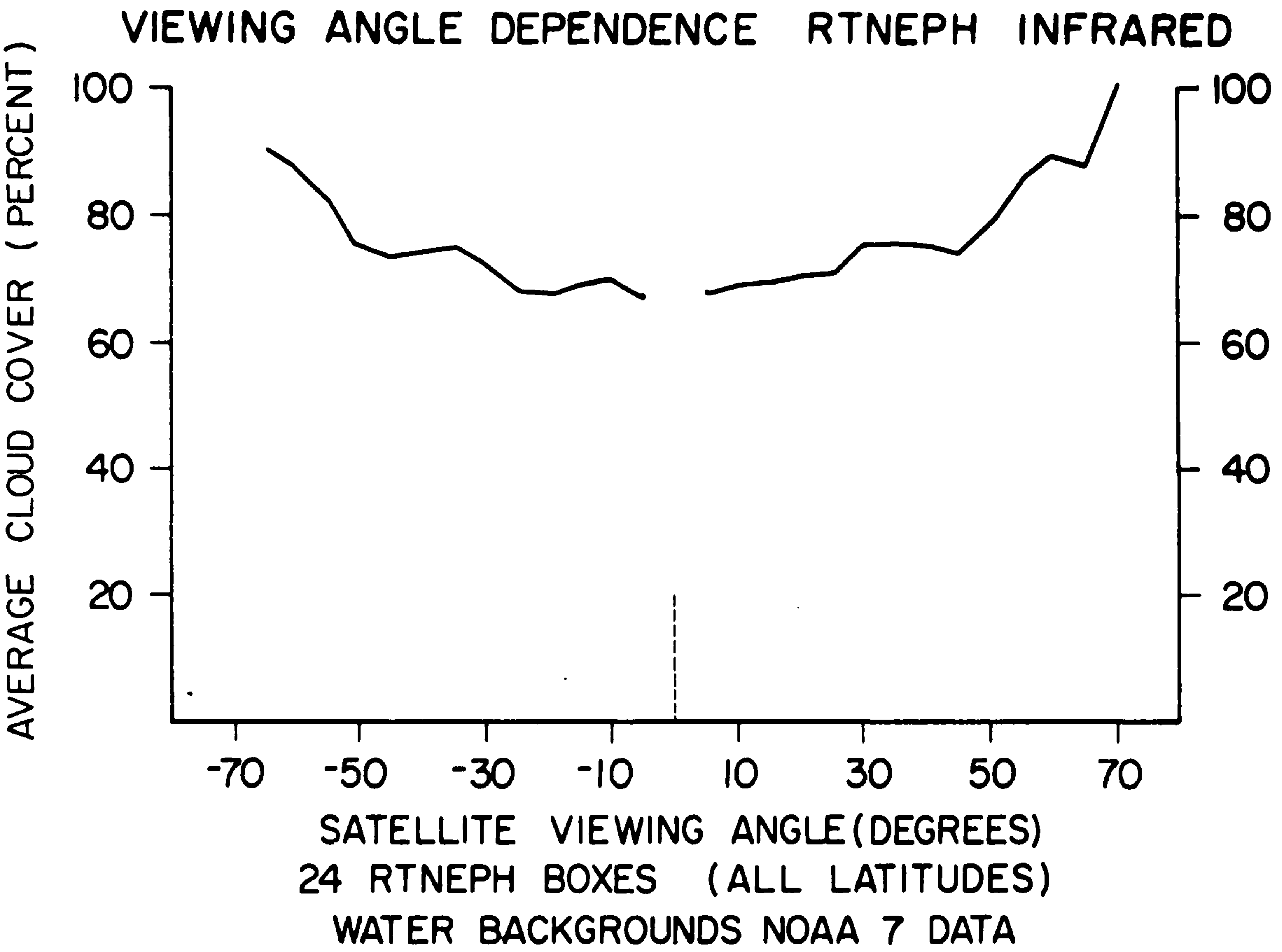
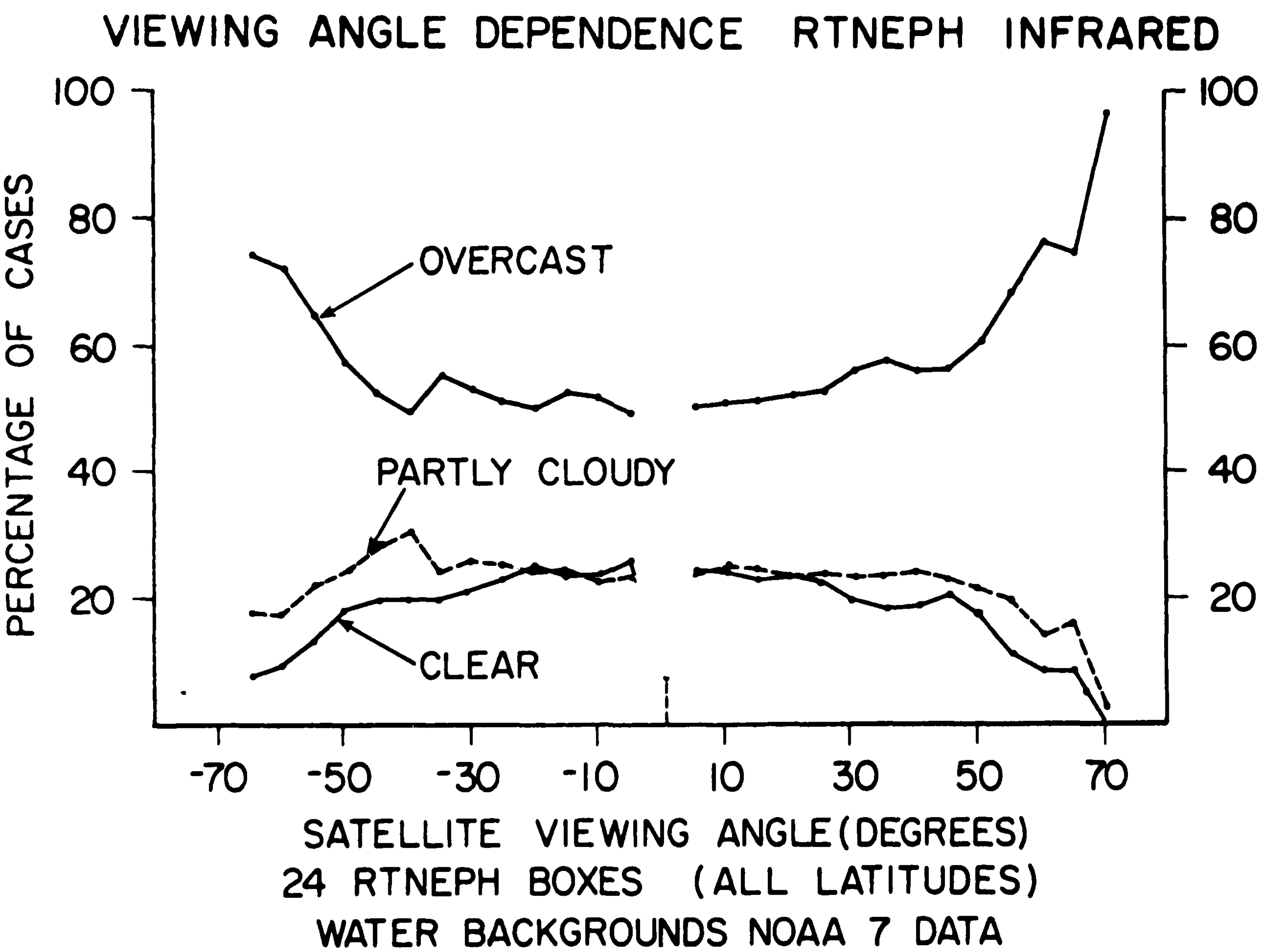
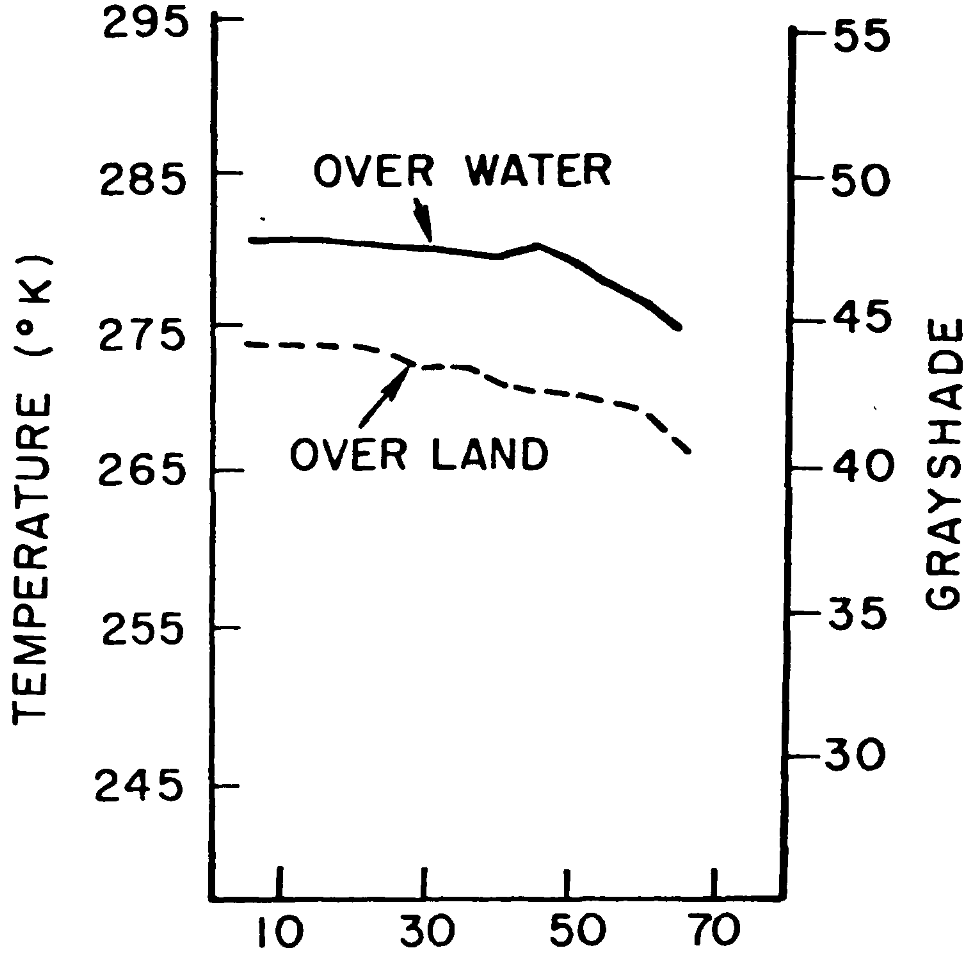
60
61
62
63
64



VIEWING ANGLE DEPENDENCE RTNEPH INFRARED
AVERAGE CLOUD COVER (PERCENT)
100
80
60
40
20
-70
-50
-30
-10
10
30
50
70
SATELLITE VIEWING ANGLE (DEGREES)
24 RTNEPH BOXES (ALL LATITUDES)
WATER BACKGROUNDS NOAA 7 DATA


VIEWING ANGLE DEPENDENCE RTNEPH INFRARED
PERCENTAGE OF CASES
100
80
60
40
20
OVERCAST
PARTLY CLOUDY
CLEAR
-70
-50
-30
-10
10
30
50
70
SATELLITE VIEWING ANGLE (DEGREES)
24 RTNEPH BOXES (ALL LATITUDES)
WATER BACKGROUNDS NOAA 7 DATA

RTNEPH INFRARED TEMPERATURES



SATELLITE VIEWING ANGLE
DMSP F-6 AND NOAA 7 DATA
DECEMBER 1983, N. H

TENTATIVE CONCLUSIONS ON SATELLITE VIEWING ANGLE BIAS

- SIGNIFICANT BIAS OVER WATER BACKGROUNDS
- BIAS OVER LAND BACKGROUNDS NOT OBVIOUS
- ATMOSPHERIC TRANSMISSION MOST LIKELY CAUSE FOR INFRARED AND VISUAL DATA

NEAR-TERM WORK ON SATELLITE VIEWING ANGLE BIAS

- DETERMINE BIAS IN INFRARED AND VISUAL DATA
- COMPARE TEMPERATURE ADJUSTMENTS WITH AFGL TRANSMISSION CODES
- DETERMINE BIAS OVER LAND BACKGROUNDS
- REMOVE BIAS FOR WATER BACKGROUNDS, INFRARED DATA

CLOUD PHOTOGRAPHY FROM STS-14

OBSERVE FIXED LOCATIONS DURING STS PASSES

PHOTOGRAPHY BY STS CREW

DATA NEEDED FOR VIEWING-ANGLE BIAS AND EARTH COVER VS. SKY COVER STUDIES

OPPORTUNITIES ON LATER STS FLIGHTS

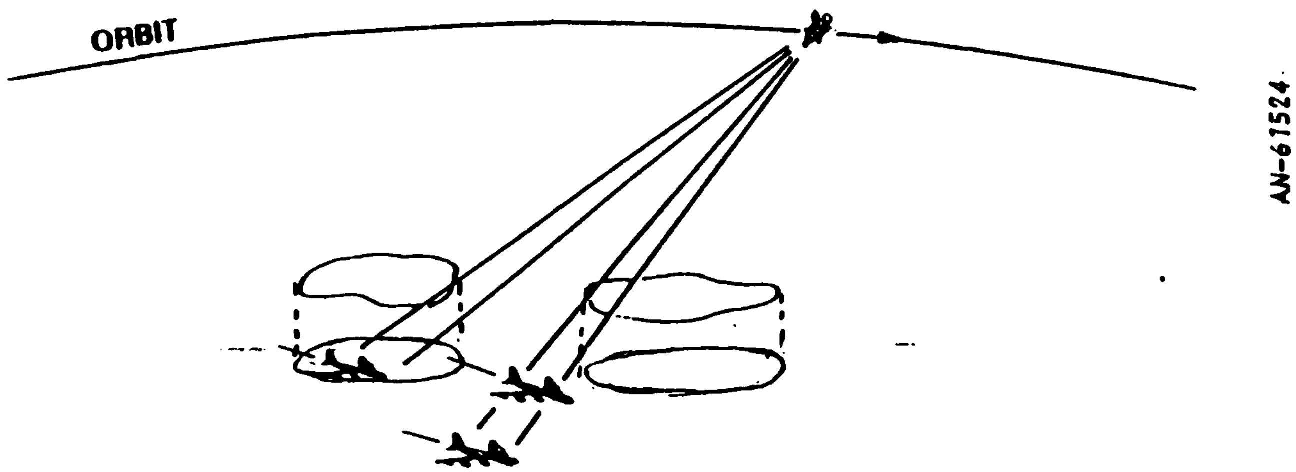
DIGITAL IMAGING AND ANALYSIS USING CLOUD CLIMATOLOGY DATA (FROM SATELLITES)

T. Vonder Haar
T. Brubaker
Colorado State University

UNCLASSIFIED

(U) CLOUDS

Typical Application



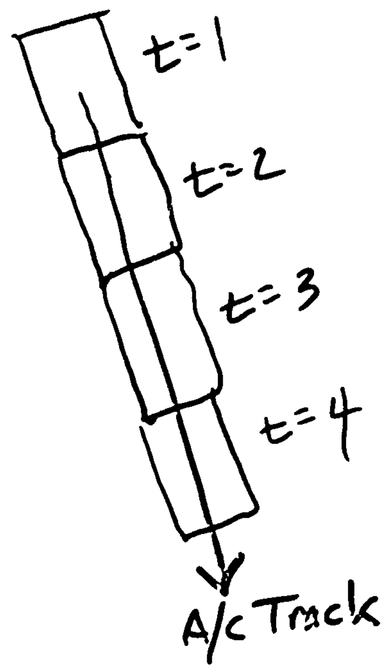
Satellite
Data Base

Altitude of Plane → Code → Circles in plane (lat., long., radius)

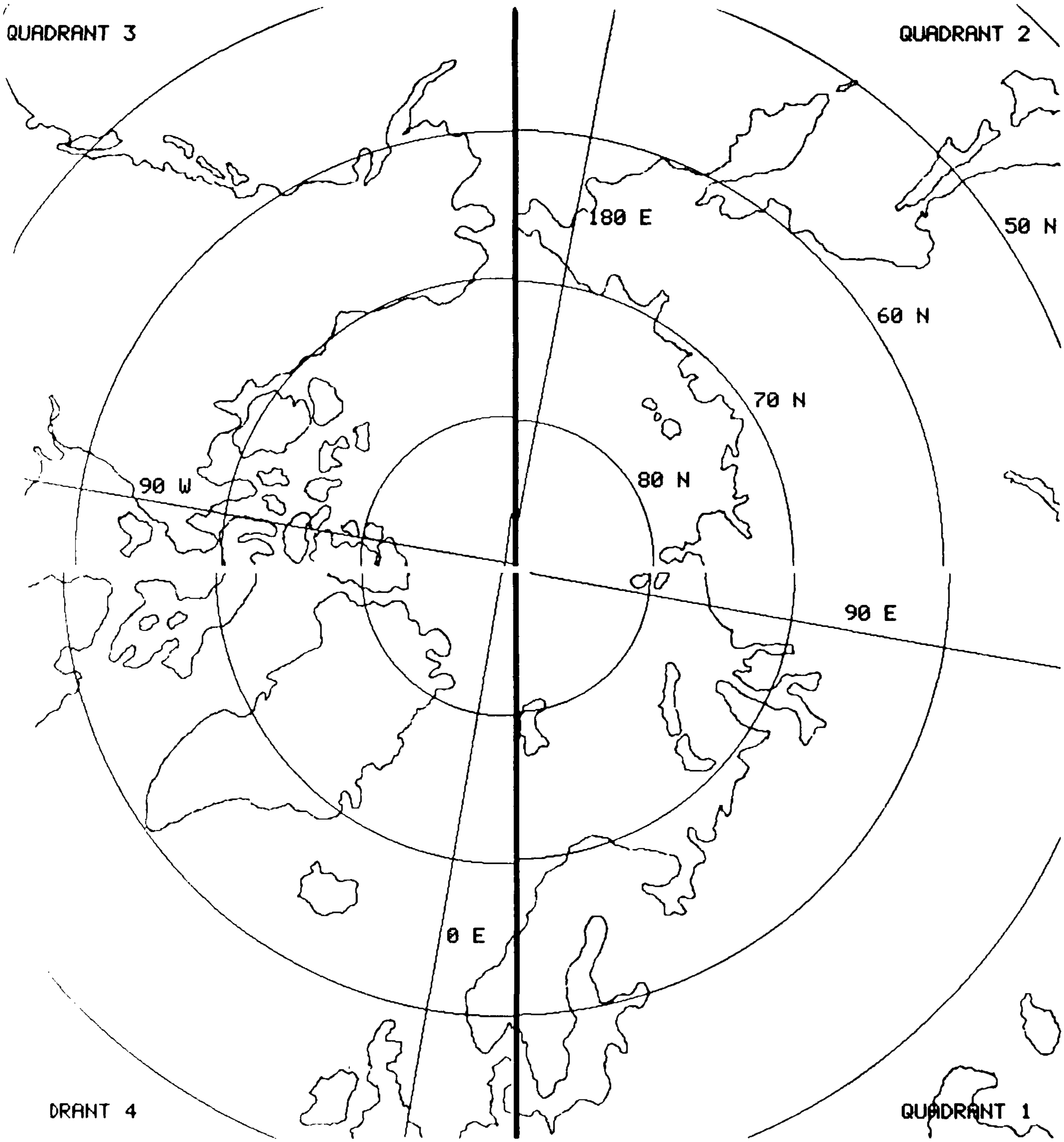
MODEL REQUIREMENTS

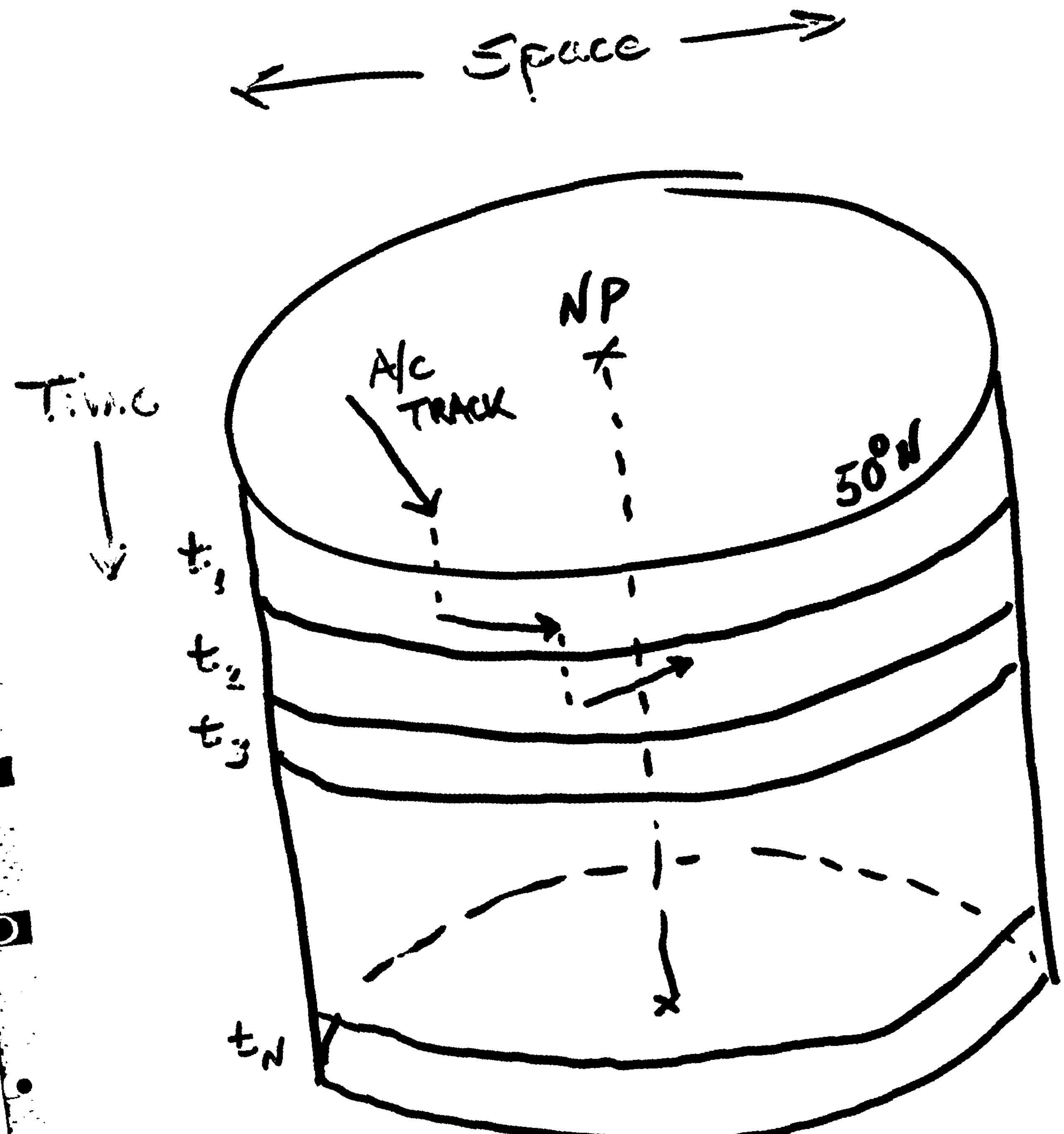
- TWO GEOGRAPHIC AREAS
- TWO WEATHER CONDITIONS
  - AVERAGE
  - POOR
- TIME REQUIREMENTS
  - I -- 24 HOURS/FOUR CORRELATED BANDS
  - II -- 24 HOURS
- CODING TO EXTRACT DATA FROM DATA BASE FOR DEFINED FLIGHT CORRIDORS
- RESOLUTION
  - 2 n. mi. DATA BASE
  - 1/2 HOUR UPDATES $\Delta t = 3$ HR
- ~~BINARY CLOUDS REPRESENTED AS CIRCLES PROJECTED ON HORIZONTAL PLANE~~

15 cloud levels selected

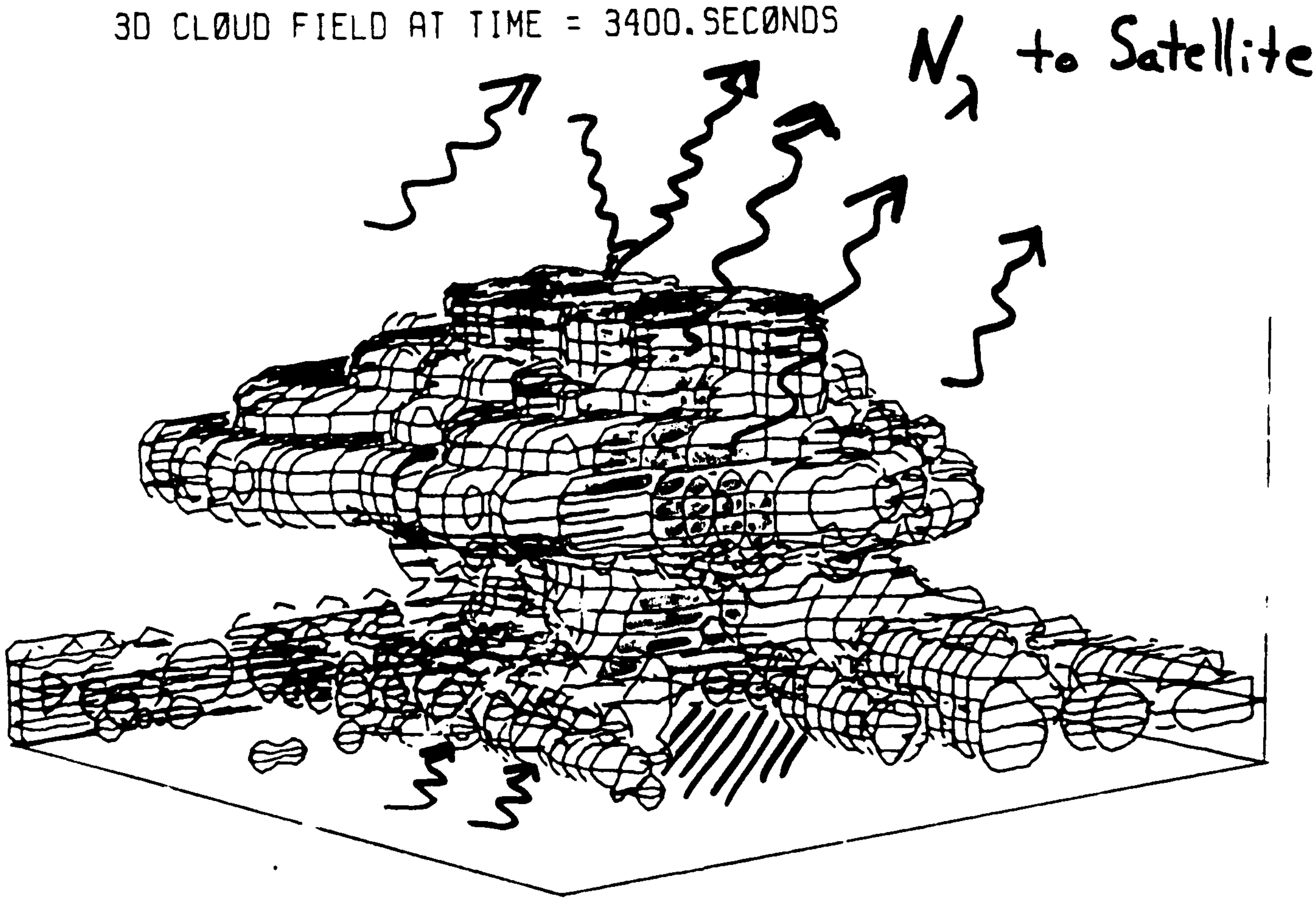


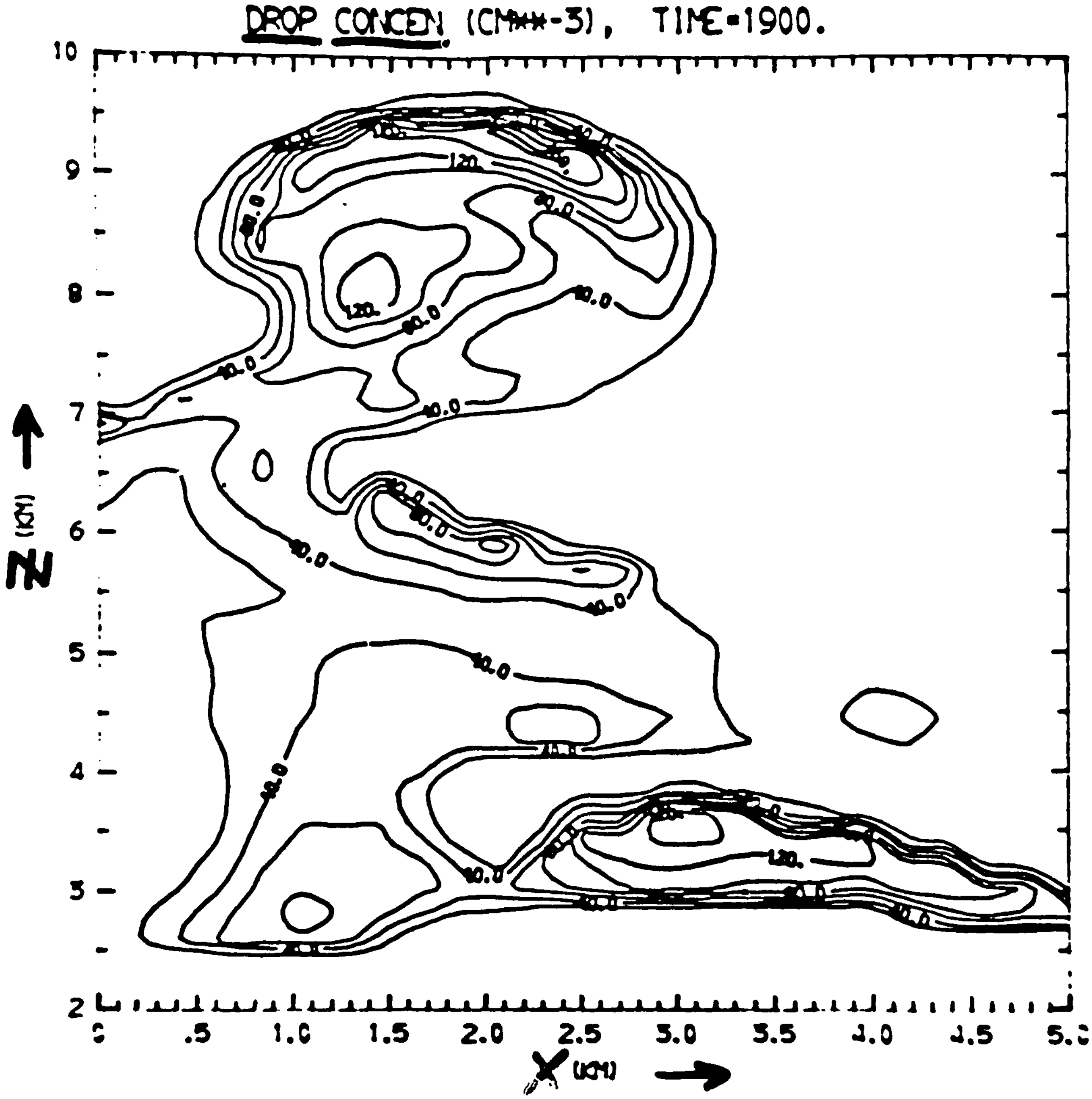
GRC


QUADRANT 3
QUADRANT 2
180 E
50 N
60 N
70 N
80 N
90 W
90 E
0 E
DRANT 4
QUADRANT 1

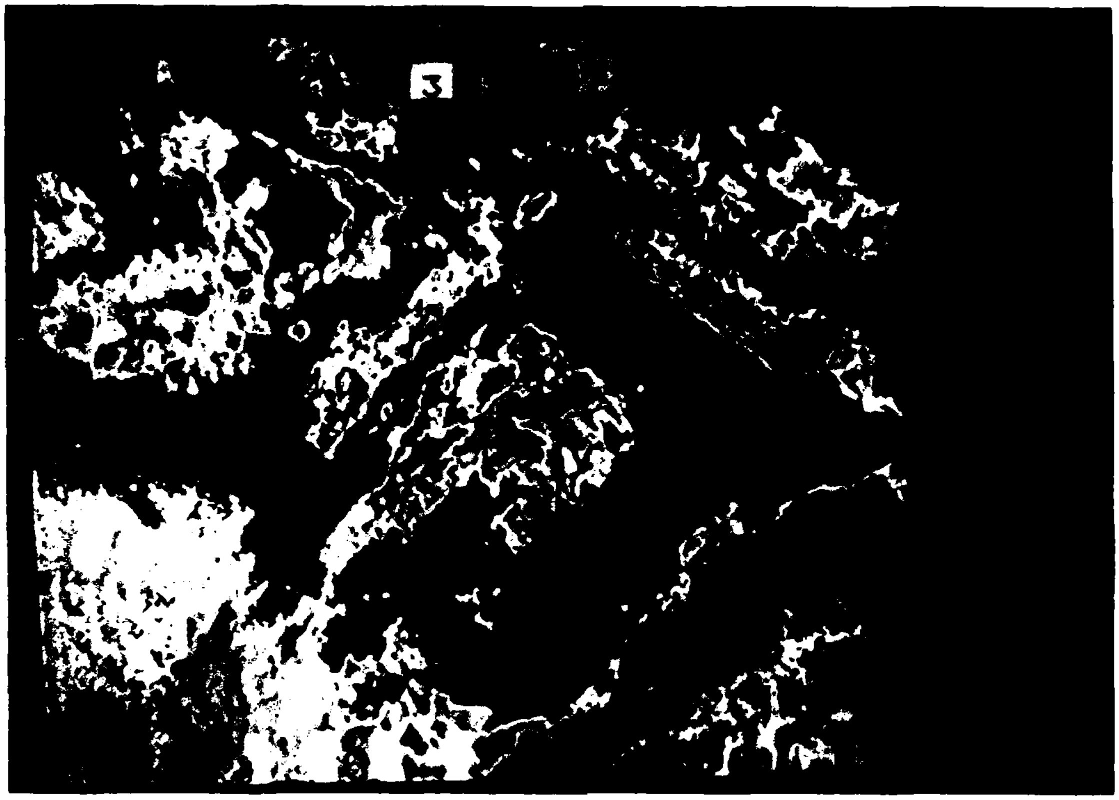


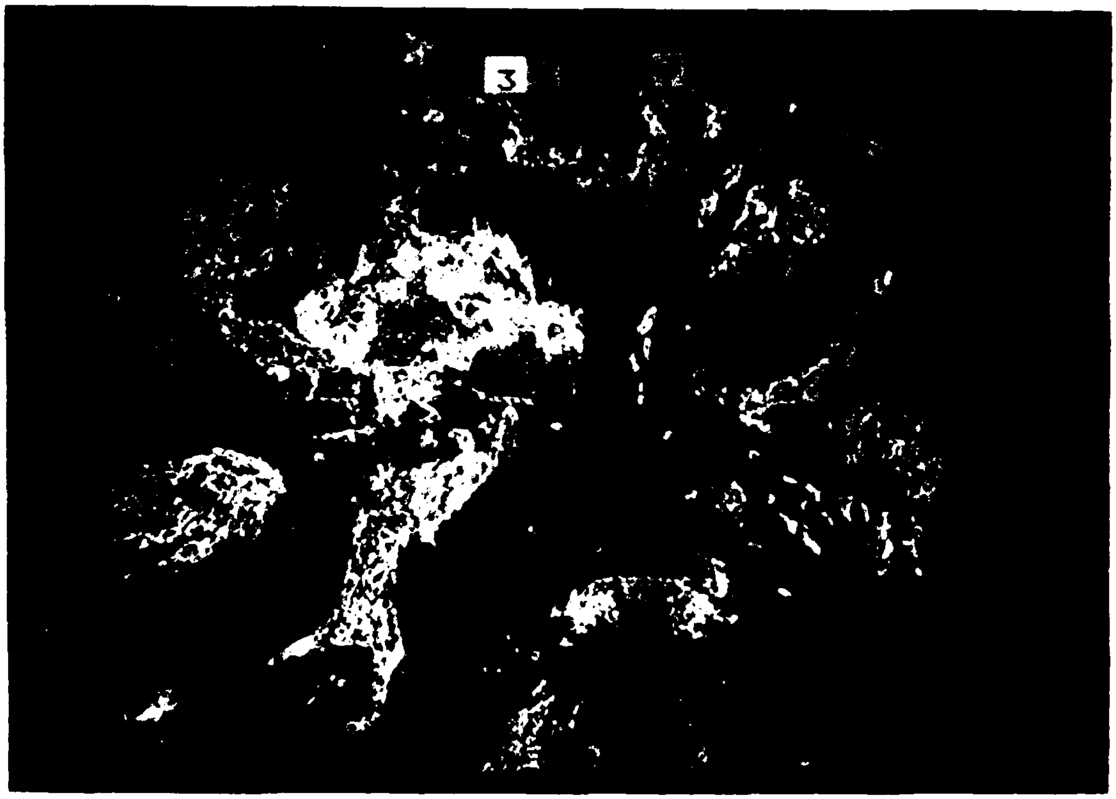
The (first) Data Base
4 days - DMSP - IR


3D CLØUD FIELD AT TIME = 3400. SECØNDS
N_λ to Satellite

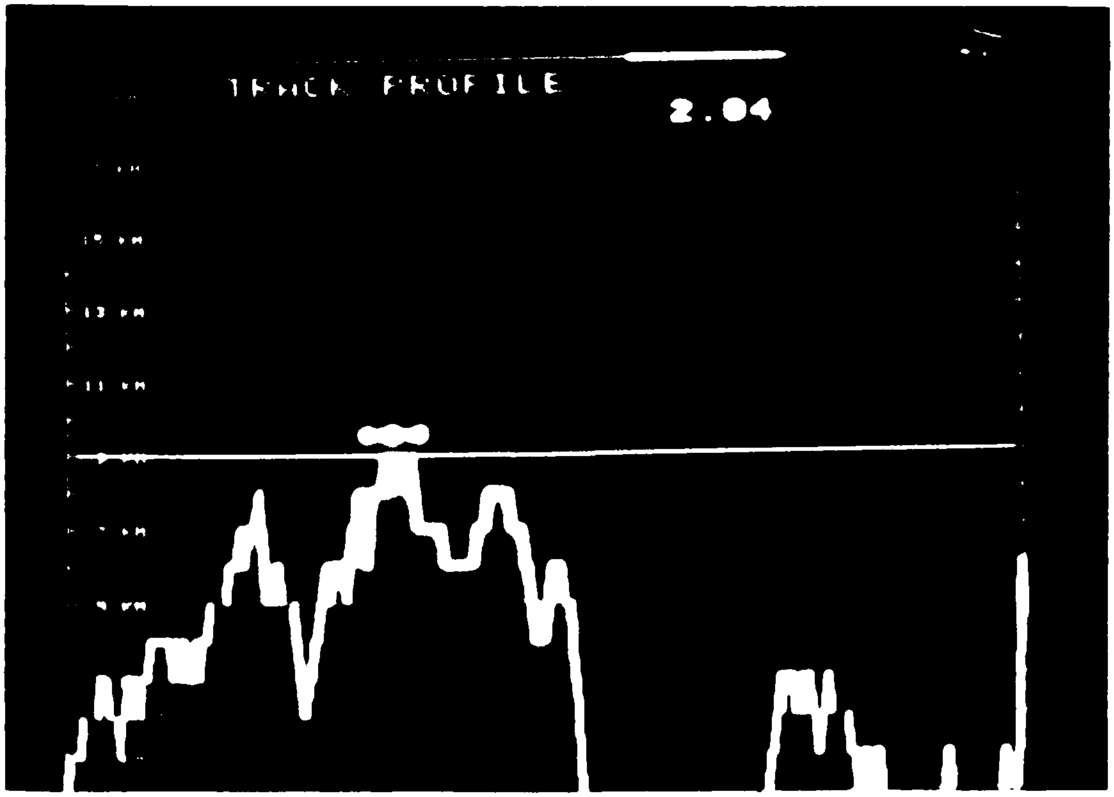


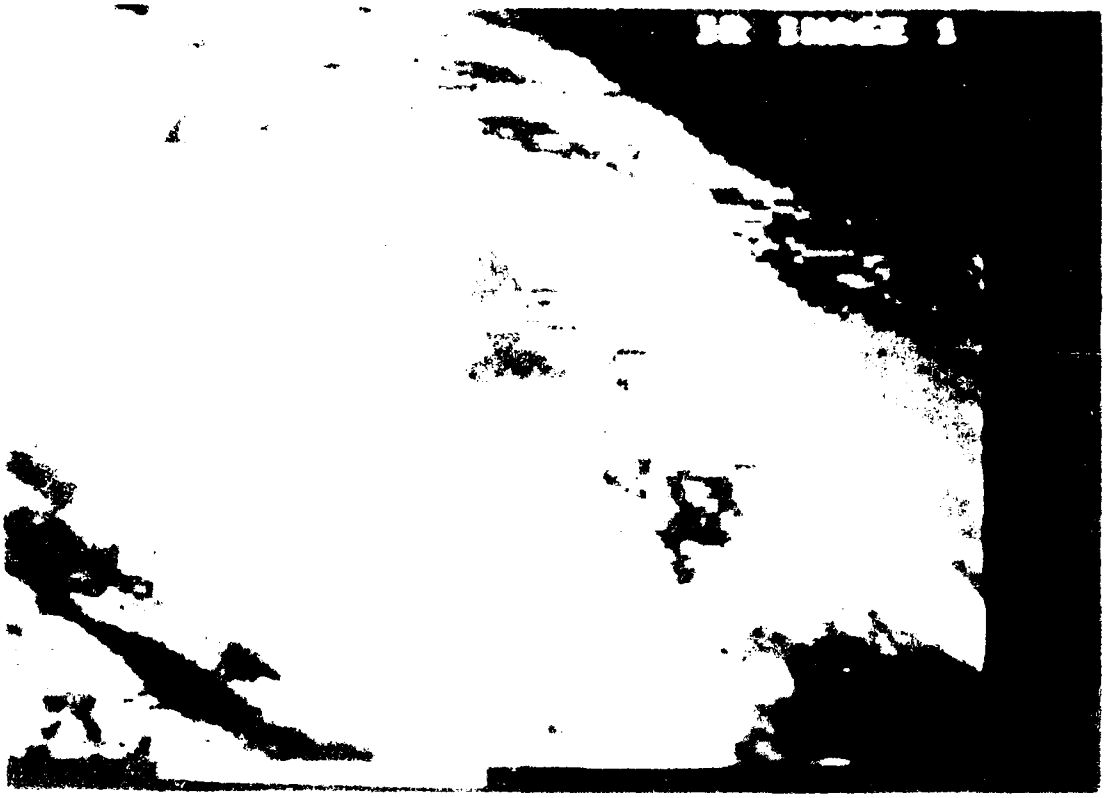
DROP CONCEN (CM**-3), TIME=1900.
10
9
8
7
6
5
4
3
2
Z (KM)
0
.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
X (KM)
120.
80.0
40.0


3


3


C
QUADRANT A
IMAGE
A


2.04



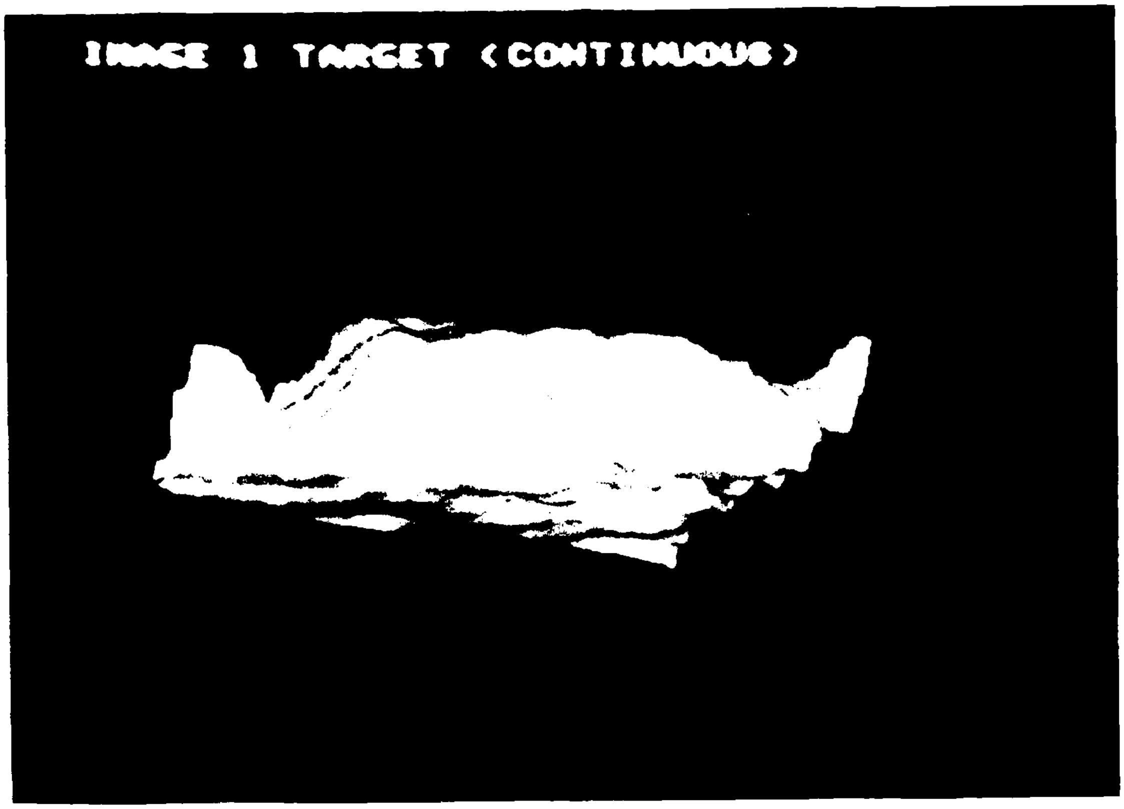
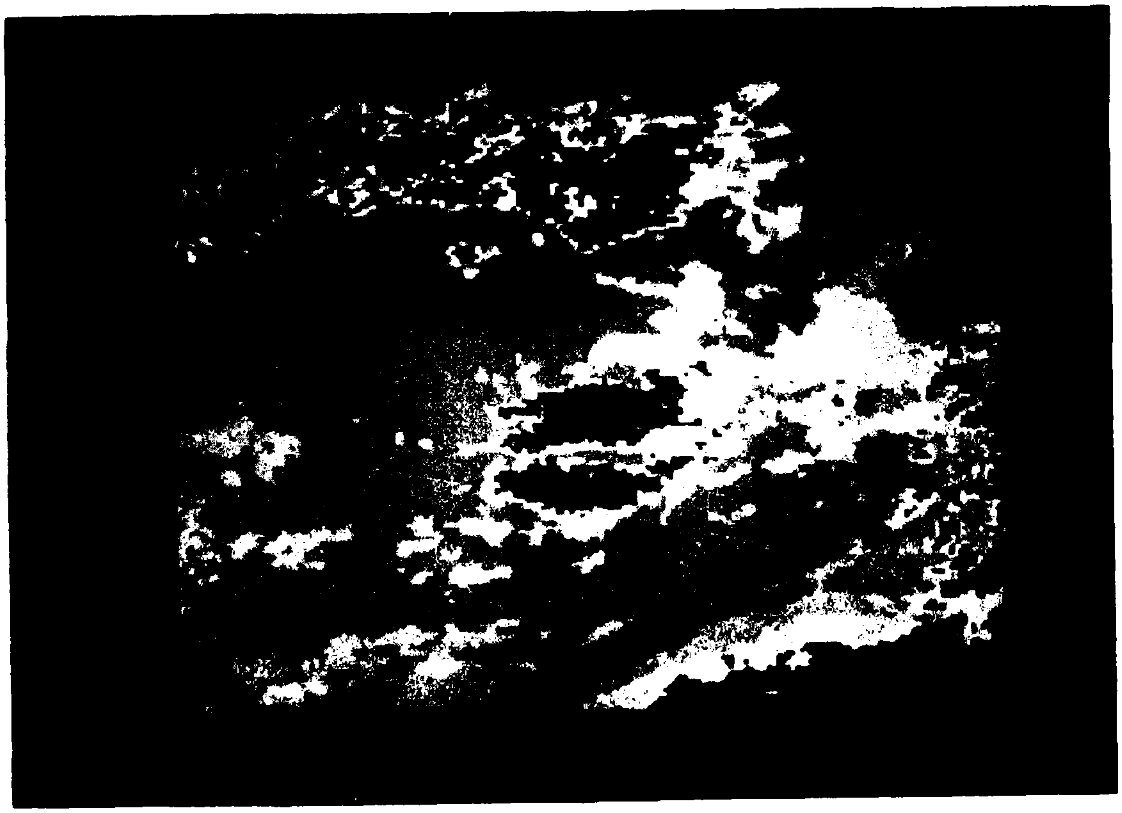
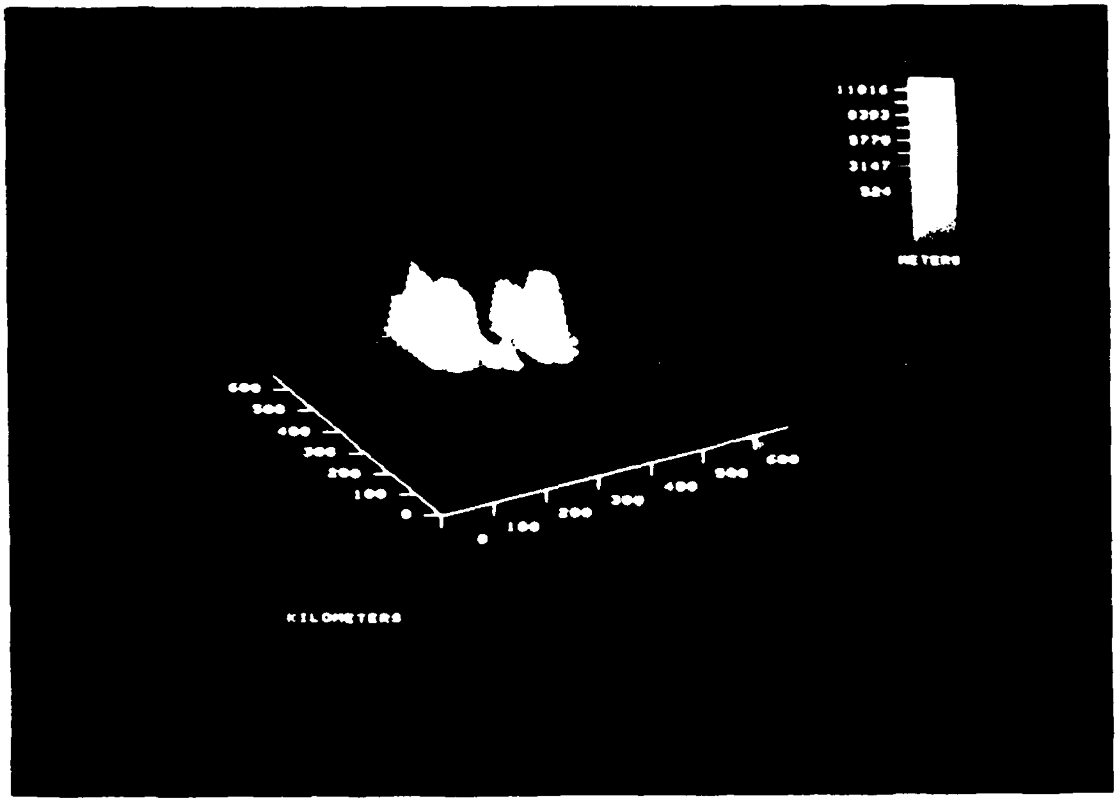


IMAGE 1 TARGET (CONTINUOUS)




11016
3147
600
500
400
300
200
100
0
0
100
200
300
400
500
600
KILOMETERS

A NEW DATA BASE OF CLOUD VARIABLES FOR ALTITUDES UP TO 10,000 FEET AGL AND THE IMPLICATIONS FOR LOW ALTITUDE AIRCRAFT ICING

Richard K. Jeck
Naval Research Laboratory

A New Data Base of Supercooled Cloud Variables for Altitudes up to 10,000 Feet AGL and the Implications for Low Altitude Aircraft Icing

Richard K. Jeck

Atmospheric Physics Branch
Environmental Sciences Division
Naval Research Laboratory
Washington, D. C. 20375

August 1983

Final Report

This document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

US Department of Transportation
Federal Aviation Administration
Technical Center
Atlantic City Airport, N.J. 08405

DOT/FAA/CT-83/21
(NRL Report 8738)

Abstract

A NEW DATA BASE OF CLOUD VARIABLES AT SUBFREEZING TEMPERATURES*

Richard K. Jeck
Naval Research Laboratory
Washington, DC 20375

About 9000 miles of airborne measurements at various altitudes above the freezing level in a wide variety of cloud types and weather conditions have been computerized to form a new data base of cloud variables at subfreezing temperatures. About half of the data is from the aircraft-icing research flights conducted by the National Advisory Committee for Aeronautics (NACA) in 1946-50. The other half is from recent flights by a variety of government, university, and corporate research aircraft equipped with modern cloud physics instrumentation. Most of the data is from research flights over the conterminous United States and nearby offshore areas. The data base includes liquid water content (LWC), cloud droplet median volume diameter, true outside air temperature at flight level, altitude and information on precipitation, ice particle concentrations, cloud type and distribution, weather conditions, date, geographic location, and other data.

Currently the data base emphasizes wintertime clouds below 10,000 ft AGL, but data are now being added for high altitude measurements in winter storms and in summertime convective clouds. A small amount of foreign data (from northern Spain) is already included and other foreign measurements will be added in the future. Data on size distributions, shapes, and other characteristics of snow and ice particles are planned for later

*Research Sponsored by the Federal Aviation Administration

inclusion too. Measurements from warm clouds can be added easily if there is a requirement.

The data base is particularly useful for applications such as:

a) Verifying the USAF 3D-NEPH procedure and the Smith-Feddes LWC and droplet size add-on procedure, by providing air truth data for a number of individual cases.

In addition, the basic assumptions underlying the Smith-Feddes model, such as the dependence of LWC and dropsize on temperature and altitude above cloud base, can be evaluated statistically for accuracy and reliability.

b) Characterizing the optical thickness, LWC, droplet size, cloud composition, or other variables as a function of cloud type, airmass, weather condition, altitude, temperature, and geographic location.

c) Performing frequency of occurrence, probability of exceedance, and multivariate analyses on cloud variables.

d) Determining extreme values of cloud variables and identifying the weather conditions, temperatures, altitudes, geographic locations, etc., where they may be encountered.

Actual examples of the above types of applications will be given.

Security class.: Unclassified

TABLE A-1. DATA CODING SCHEME

First Card of each Data Suite

Item	Code	Card Columns
Mission Identifier (Flight No. or Cloud No.)	XXXXXXX	1-7
Date of Measurement	MMDDYY	8-13
Geographic Location	GG or GGG	14-16
Source of Data:		
Agency	LLL or LLLL	17-20
Reference (Publication ID or Report No.)	ZZ ------ ZZ	21-36
Altitude Reporting Convention:		
Scale used for data in this suite	A	37
Elevation of local surface (hundreds of feet, ASL)	FF or M	38-39
Cloud Information:		
Cloud type	CC or CCCc	40-43
Uniformity	G	44
Cloud base altitude (hundreds of feet)	BBB	45-47
Cloud base temperature (°C)	±WW.W	48-52
Cloud top altitude (hundreds of feet)	HHH	53-55
Cloud top temperature (°C)	-YY.Y	56-60
Weather Factors:		
Airmass type	aAa or Ma	61-63
Weather description	cc --- cc	64-79
Card 1 indicator	1	80

Second and Following Cards of each Data Suite

Item	Code	Card Columns
Time of Day for Event	hhmm+h	1-6
Icing Event Information:		
Event No	ee	7-8
Defining criterion	f	9
Duration (min.)	mm or .m	10-11
Distance in cloud (nmi)	dd or .d	12-13
Aircraft State during Event:		
Sampling maneuver	s	14
Airspeed (kt)	vvv	15-17
Altitude (ft)	aaaaa	18-22
Outside Air temperature (°C)	+tt.t	23-27
LWC Meter Data:		
LWC (g/m^3)	w.w or .ww	28-30
Probe ID	pp	31-32

TABLE A-1. DATA CODING SCHEME (Continued)

Item	Code	Card Columns
Droplet Probe Data:		
LWC (g/m^3)	w.w or .ww	33-35
MVD (μm)	uu	36-37
Max droplet diameter (μm)	zz	38-39
N (no/cc)	nnn	40-42
Probe ID	pp	43-44
Precipitation or Other Large Particle Probe Data:		
PMS 2D-C Probe concentration	n.n or .nn	45-47
(Particles per liter)	n.n or .nn	48-50
PMS 2D-P Probe " " " " "	nn or .n	51-52
PMS 1D (OAP) Probe " " "	nn or .n	53-54
Other Ice Particle Counter " Probe ID	P	55
Ice Meter Data:		
LWC (g/m^3)	w.w or .ww	56-58
Icing rate (g cm^{-2} $hour^{-1}$ or cm/hour)	i.ir or .iir	59-62
Probe ID	pp	63-64
Ice Meter Data (2nd probe, if used)		
LWC (g/m^3)	w.w or .ww	65-67
Icing rate (g cm^{-2} $hour^{-1}$ or cm/hour)	i.ir or .iir	68-71
Probe ID	pp	72-73
Weather Factors:		
Precip. during measurements (type & intensity)	q+ or qq	74-75
State of cloud particles	ssss	76-79
Card 2 indicator	2	80

TABLE A-4. THE NEW SUPERCOOLED CLOUD DATA BASE (Continued)
Data File No. 25

```
    ----------------------------Card Column No.-------------------------------------
             11111111112222222222333333333344444444445555555555666666666677777777778
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
Rec.
No.                                  Card (Record) Contents
 1 Cloud3 013081DDC UWY Priv Comm 55/81S24StScC 25 -5.6 45 -8.4cP Hp,SrI45         1
 2 19164213P N NP158 4535 -8.4.18JW.2112 m216 F3.4 .253 NN N *9 cR0 X  N  CS U  U 2
 3 19171814P N NP163 4030 -8.1.31JW.2812 m283 F11  0 99 NN N *9 cR0 X  N  CS U  U 2
 4 19:17 15E 3 7L151 3740 -7.4.20JW.2412 m258 F9.1 0  m NN N 8.2cR0 X  N  CS U  U 2
 5 19204817P N NP157 3190 -6.8.22JW.1910 m405 F8.6 .186 NN N 7.5cR0 X  N  CS U  U 2
 6 19:21 18E.8 2L147 2620 -5.7.05JW.07 7 m322 F11  .2 m NN N *3 cR0 X  N  CS U  U 2
 7 19225419P N NP138 3190 -6.8.17JW.2010 m343 F14  .198 NN N *7 cR0 X  N  CS U  U 2
 8 19231820P N NP142 3620 -7.3.21JW.2612 m321 F12  0 99 NN N *7 cR0 X  N  CS U  U 2
 9 19235421P N NP150 4115 -7.5.12JW.2215 m138 F12  0 99 NN N *10cR0 X  N  CS U  U 2
10 19242422P N NP154 4365 -7.8.18JW.1812 m176 F7.4 0 68 NN N  U cR0 X  N  CS U  U 2
11 Cloud4 013081wKS UWY Priv Comm 5/81 S24StScB*26*-5.7*47*-8.5cP Hp,SrI47         1
12 19:30 E18.5 1L169 4690 -7.4.17JW.1512 m142 F .2 .2 0 NN N *6 cR0 X  N  CS U  U 2
13 19:32 E28 1 3L171 4650 -8.3.20JW.1612 m167 F4.0 0 19 NN N *7 cR0 X  N  CS U  U 2
14 19:34 E3D 2 4L167 4645 -7.5.12JW.1111 m147 F .7 0  m NN N 4.5cR0 X  N  CS U  U 2
15 19:36 E4J 411L160 4640 -8.4.20JW.1812 m176 F11  0  m NN N 8.5cR0 X  N  CS U  U 2
16 19:41 E5J 513L156 4650 -8.5.22JW.1111 m169 F11  0 99 NN N 9.0cR0 X  N  CS U  U 2
17 19:48 E6A1128L159 4645 -8.8.19JW.0910 m178 F11  0  m NN N 5.5cR0 X  N  CS U  U 2
18 Cloud5 013081MCK UWY Priv Comm 5/81 S24 St C 29 -8.7 53-10.5cP Hp,SrI53         1
19 202048F1P N NP185 5315 -9.1.23JW.1915 m103 F3.3 .228 NN N *7 cR0 X  N  CS U  U 2
20 202124F2P N NP178 4800-11.2.17JW.1214 m 88 F14  .199 NN N *6 cR0 X  N  CS U  U 2
21 202154F3P N NP175 4300 -9.2.16JW.0912 m109 F15  .199 NN N *6 cR0 X  N  CS U  U 2
22 20:22 F4E 2 4L156 3850 -9.7.11JW.10 9 m250 F11  .199 NN N 5.5cR0 X  N  CS U  U 2
23 202506F5P N NP163 3325 -9.2.05JW.03 7 m137 F9.2 .179 NN N <1 cR0 X  N  CS U  U 2
24 202542F6P N NP161 3005 -8.7.03JW.02 6 m230 F3.5 .222 NN N <1 cR0 X  N  CS U  U 2
25 203006G1P N NP151 3110 -9.1.04JW.02 7 m155 F11  .593 NN N *6 cR0 X  N  CS U  U 2
26 203024G2P N NP147 3610-10.1.10JW.10 9 m320 F13  .299 NN N *6 cR0 X  N  CS U  U 2
27 203100G3P N NP155 4125 -9.4.05JW.0912 m107 F9.1 .168 NN N *6 cR0 X  N  CS U  U 2
28 20:32 G4A1429L157 4810 -9.9.16JW.1915 m108 F12  0 99 NN N 8.5cR0 X  N  CS U  U 2
29 Cloud1 013181LBF UWY Priv Comm 5/81 S28 Sc B 51 -8.3 64-11.2cP U,CILO            1
30 18:13 A6E 513L166 6200-10.9.14JW.1612 m165 F2.0 .3 m NN N 7.2cR0 m  N  CS UmW+I2
31 181848A7P N NP179 5625 -9.5.11JW.0911 m121 F5.3 .738 NN N *7 cR0.10 N  CSS-mW+I2
32 182006A6P N NP174 5110 -8.3.09JW.04 9 m 95 F6.2 .853 NN N  U cR0.05 N  CSS-mW+I2
33 18282481P N NP144 5205 -8.6 0 JW.02 6 m176 F2.3 .6 4 NN N  0 cR0 0  N  CS UmW+I2
34 18284882P N NP151 5765 -9.9.04JW.06 7 m314 F1.0 .2 9 NN N *<1cR0.05 N  CS UmW  2
35 18290683P N NP148 6235-10.8.22JW.2111 m305 F1.3 .3 6 NN N  U cR0.22 N  CS UmW  2
36 Cloud2 013181LBF UWYPriv Comm 5/81  S28 St V 75-11.0 90 -9.2cP U,CILOWkI75      1
37 183000C1P N NP152 7500-11.0.01JW.03 7 m 76 F2.1 .747 NN N  <1cR0.02 N  CSS- W+I2
38 183036C2P N NP159 8125-10.2.02JW.02 9 m 56 F2.1 .819 NN N  <1cR0.03 N  CSS- W+I2
39 183054C3P N NP151 8540 -9.6.04JW.05 9 m119 F2.61.236 NN N  <1cR0.04 N  CSS- W+I2
40 183118C4P N NP156 8900 -9.4.04JW.05 9 m165 F1.8 .717 NN N *<1cR0.05 N  CSS-mW+I2
41 Cloud3 013181LBF UWY Priv Comm 5/81 S28 St V110 -9.7129-13.3cP U,ThCILO          1
42 183312D1P N NP16511050 -9.7.02JW.03 5 m167 F1.8 .8 9 NN N  <1cR0.02 N  CSS-mW  2
43 183336D2P N NP16611540-10.8.10JW.10 9 m278 F2.4 .7 8 NN N  U cR0.11 N  CSS-mW+I2
44 183406D3P N NP17012035-11.6.10JW.11 9 m260 F2.7 .817 NN N *6 cR0.12 N  CSS-mW+I2
45 183430D4P N NP16312560-12.6.13JW.1410 m254 F2.0 .926 NN N  U cR0.16 N  CSS-mW+I2
46 183454D5P N NP17012940-13.3.04JW.05 9 m 91 F1.4 .313 NN N *<1cR0.03 N  CS U W+I2
47 Cloud4 013181LBF UWY Priv Comm 5/81 S28 St I144-16.7150-17.8cP U,noI>100        1
48 183624E1P N NP17314430-17.3.01JW.01 6 m152 F4.01.415 NN N *0 cR0 0  N  CSS-W?IS2
49 183654E2P N NP17214930-17.6.02JW.02 6 m247 F2.5 0  4 NN N *0 cR0 0  N  CS 0W?+I2
50 Cloud5 013181CDR UWY Priv Comm 5/81 S33 Sc C U  U     U    U  cP U,*CILO         1
51 19:43 G1G.7 2L177 6105-11.4.02JW.01 7 m 59 F8.61.224 NN N *<1cR0.02 N  CSS-mI+S2
52 19:44 G2D 411L174 6295-12.0.05JW.05 9 m145 F4.1 .5 m NN N 3.0cR0 m  N  CS UmW+I2
53 19:47 G3D 2 6L178 6355-12.0.13JW.1110 m219 F2.7 .3*7 NN N 5.0cR0 m  N  CS UmW+I2
54 19:49 G4A 3 7L172 6310-11.6.03JW.03 7 m173 F[illegible] [illegible] NN N *2 cR0 m  N  CS UmW+I2
55 Cloud6 013181SNY UWY Priv Comm 5/81 S42 St I U   U    U    U  cP U               1
56 17:48 A1J.9 3L169 6170-10.5.11JW.10 9 m225 F1.8 .4 m NN N  U  R0 m  N  CS UmW+I2
57 17:51 A2J 2 4L172 6175-10.3.08JW.10 9 m234 F1.8 .3 m NN N *2 cR0 m  N  CS UmW+I2
             11111111112222222222333333333344444444445555555555666666666677777777778
    12345678901234567890123456789012345678901234567890123456789012345678901234567890
```

Sample Application of the NRL/FAA Data Base.

TABLE D-1. COMPARISON OF MAXIMUM LWCs FROM USAF/ETAC (SMITH-FEDDES) CLOUD WATER MODEL WITH MAXIMUM OBSERVED LWCs IN THE NEW DATA BASE

Temperature in Cloud at Flight Level:	For Stratus (St) Clouds -25 to -20°C	-20 to -15°C	-15 to -10°C	-10 to -5°C	-5 to 0°C	For Stratocumulus (Sc) Clouds -25 to -20°C	-20 to -15°C	-15 to -10°C	-10 to -5°C	-5 to 0°C	For Nimbostratus (Ns) Clouds -25 to -20°C	-20 to -15°C	-15 to -10°C	-10 to -5°C	-5 to 0°C
New CONUS LWC Data Base															
Maximum LWC observed below 10,000 ft AGL	.30	.50	.70	.60	.70	.50	.50	.70	.90	1.10	---	---	---	---	.20
99.9 percentile value of LWC	.30	.49	.64	.57	.68	.49	.50	.64	.89	.91	---	---	---	---	.20
99 " " " "	.27	.43	.40	.46	.57	.44	.46	.52	.85	.59	---	---	---	---	.19
95 " " " "	.20	.20	.36	.30	.47	.38	.30	.39	.51	.51	---	---	---	---	.17
90 " " " "	.19	.19	.32	.27	.42	.36	.28	.37	.41	.45	---	---	---	---	.15
No. of Data Miles represented in given temperature interval:	136	73	624	761	375	61	172	590	1248	842	0	0	0	0	27
USAF/ETAC Max. LWC for all Altitudes	.15	.20	.25	.30	.35	.30	.40	.45	.50	.55	.40	.45	.50	.60	.60
%tile ranking in new CONUS Data Base	(70%)	(95%)	(80%)	(95%)	(80%)	80%	98%	97%	95%	97%	-	-	-	-	[>Max]

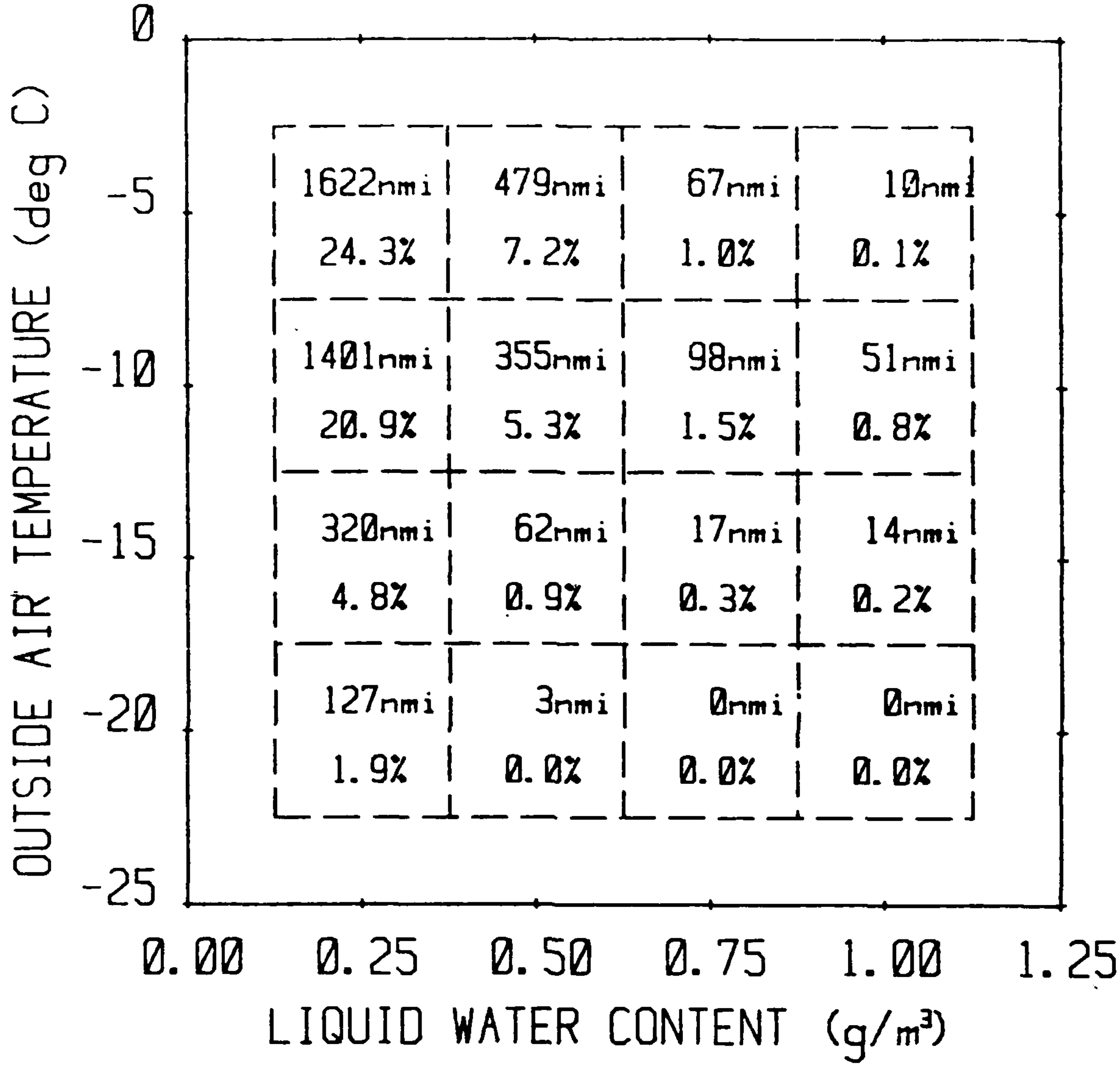
Temperature in Cloud at Flight Level:	For Altostratus (As) Clouds -25 to -20°C	-20 to -15°C	-15 to -10°C	-10 to -5°C	-5 to 0°C	For Altocumulus (Ac) Clouds -25 to -20°C	-20 to -15°C	-15 to -10°C	-10 to -5°C	-5 to 0°C
New CONUS LWC Data Base										
Maximum LWC observed below 10,000 ft AGL	---	---	.20	.50	.50	---	---	.30	.70	.50
99.9 percentile value of LWC	---	---	.20	.49	.50	---	---	.30	.68	.50
99 " " " "	---	---	.18	.45	.47	---	---	.29	.51	.49
95 " " " "	---	---	.10	.30	.37	---	---	.26	.39	.44
90 " " " "	---	---	.09	.27	.27	---	---	.21	.36	.39
No. of Data Miles represented in given temperature interval:	0	0	60	164	53	0	0	195	190	47
USAF/ETAC Max. LWC for all Altitudes	.20	.25	.30	.30	.35	.30	.35	.40	.40	.45
%tile ranking in new CONUS Data Base	---	---	>Max	(95%)	(95%)	---	---	>Max	95%	95%

Notes: 1. Values in parentheses () for St and As may be slightly underestimated because in the new Data Base the actual cloud type was not always distinguishable from similar types, i.e., Sc and Ac, respectively, which may occasionally contain slightly greater LWCs.

2. Values in brackets [] are uncertain because of an inadequate number of samples in the new Data Base.

Temperature in Cloud at Flight Level:	For Cumulus (Cu) Clouds -25 to -20°C	-20 to -15°C	-15 to -10°C	-10 to -5°C	-5 to 0°C	For Cumulonimbus (Cb) Clouds -25 to -20°C	-20 to -15°C	-15 to -10°C	-10 to -5°C	-5 to 0°C	For Orographic (Or) Clouds[a] -25 to -20°C	-20 to -15°C	-15 to -10°C	-10 to -5°C	-5 to 0°C
New CONUS LWC Data Base															
Maximum LWC observed below 10,000 ft AGL	---	.60	1.50	1.70	1.30	---	.60	1.50	1.00	1.20	---	.40	1.40	1.70	1.30
99.9 percentile value of LWC	---	.60	1.49	1.59	1.29	---	.60	1.49	1.00	1.20	---	.40	1.34	1.64	1.30
99 " " " "	---	.59	1.39	1.27	1.23	---	.60	1.45	.96	1.19	---	.40	1.34	1.27	1.28
95 " " " "	---	.57	1.07	1.02	1.00	---	.59	.98	.72	1.16	---	.38	1.22	1.04	1.12
90 " " " "	---	.54	.92	.75	.71	---	.57	.92	.66	1.13	---	.37	1.05	.78	.68
No. of Data Miles represented in given temperature interval:	0	56	483	738	265	0	27	215	227	21	0	26	187	404	64
USAF/ETAC Max. LWC for all Altitudes	3.0	3.0	3.0	3.0	3.0	6.5	6.5	6.5	6.5	6.5	---	---	---	---	---
%tile ranking in new CONUS Data Base	---	>Max	>Max	>Max	>Max	---	>Max	>Max	>Max	>Max	---	---	---	---	---

[a] In the present context, orographic clouds refer to those formed or assisted by uplifting over the windward slopes of mountains. Lee or wave clouds are classified separately as lenticular clouds.



Sample Application of the NRL/FAA Data Base.

FIGURE C-3. DATA MILES NOTED IN THE NEW DATA BASE FOR INDICATED INTERVALS IN THE VICINITY OF EACH TEST POINT IN THE ARMY ICING MATRIX. Results apply to the altitude range 0-10,000 ft AGL. The percentages indicate the fraction of all data miles below 10,000 ft AGL that were found in the Data Base for each of the $\pm 2.5°C$ and ± 0.125 gm/m^3 intervals centered on the test "points" shown in Fig. C-1. Of 6685 data miles, 4625 (69%) fell somewhere within the 4x4 boxed area. Of the 2060 (31%) data miles which fell outside, 1840 (27.5%) were at lesser LWCs, 50 (0.9%) were at greater LWCs, 185 (2.7%) were at higher temperatures, and 24 (0.4%) were at lower temperatures.

TABLE C-4. Modern Data for OAT < -17.5 degC (Row 4 of Army Icing Test Matrix)

For the Altitude Interval of 0-5000 Ft AGL

File/Rec	Cloud Type	Geog Loc.	Air Mass	Month of Yr	OAT degC	LWC g/m^3	Data Miles	Data Source	Weather Situation
18 /49	Sc	MKG	cA	12	-17.6	0.12	1.0	UWY	Hp*bFFmCf,I56
21 / 2	St	cLM	cA	01	-19.4	0.09	3.0	UWY	U,WkI55
21 / 3	St	cLM	cA	01	-19.5	0.10	5.0	UWY	U,WkI55
21 / 4	St	cLM	cA	01	-19.9	0.06	3.0	UWY	U,WkI55
21 / 5	St	.cLM	cA	01	-20.8	0.12	1.0	UWY	U,WkI55
21 / 6	St	cLM	cA	01	-22.2	0.17	1.0	UWY	U,WkI55
21 / 7	St	cLM	cA	01	-23.1	0.17	1.0	UWY	U,WkI55
21 / 8	St	cLM	cA	01	-23.1	0.16	4.0	UWY	U,WkI55
21 / 9	St	cLM	cA	01	-21.8	0.14	17.0	UWY	U,WkI55
21 /10	St	cLM	cA	01	-21.6	0.11	20.0	UWY	U,WkI55
21 /11	St	cLM	cA	01	-22.1	0.10	5.0	UWY	U,WkI55
21 /12	St	cLM	cA	01	-22.4	0.13	6.0	UWY	U,WkI55
21 /13	St	cLM	cA	01	-22.0	0.23	2.0	UWY	U,WkI55
21 /14	St	cLM	cA	01	-22.4	0.13	2.0	UWY	U,WkI55
21 /15	St	cLM	cA	01	-22.4	0.13	18.0	UWY	U,WkI55
21 /17	Sc	cLM	cA	01	-20.3	0.07	2.0	UWY	U
21 /20	St	cLM	cA	01	-20.3	0.08	12.0	UWY	U,pC10
21 /21	St	cLM	cA	01	-20.7	0.10	20.0	UWY	U,pC10
21 /23	Sc	cLM	cA	01	-22.5	0.12	2.0	UWY	U
21 /24	Sc	cLM	cA	01	-22.2	0.08	2.0	UWY	U
21 /25	Sc	cLM	cA	01	-22.1	0.17	3.0	UWY	U
21 /26	Sc	cLM	cA	01	-21.7	0.09	2.0	UWY	U
21 /27	Sc	cLM	cA	01	-21.4	0.08	2.0	UWY	U
21 /28	Sc	cLM	cA	01	-21.3	0.10	3.0	UWY	U
21 /29	Sc	cLM	cA	01	-20.1	0.08	2.0	UWY	U
21 /34	Sc	cLM	cA	01	-18.1	0.06	1.0	UWY	U,I64
21 /35	Sc	cLM	cA	01	-19.0	0.07	1.0	UWY	U,I64
21 /44	Sc	cLM	cA	01	-18.8	0.07	6.0	UWY	U,I64
21 /45	Sc	cLM	cA	01	-18.5	0.12	7.0	UWY	U,I64
21 /46	Sc	cLM	cA	01	-18.4	0.17	6.0	UWY	U,I64
22 / 3	Sc	cLM	cA	01	-18.5	0.23	1.0	UWY	U,pCILO
22 / 6	St	cLM	cA	01	-19.4	0.10	3.0	UWY	U,WkI58,pCILO
22 / 7	St	cLM	cA	01	-19.8	0.08	4.0	UWY	U,WkI58,pCILO
22 / 8	St	cLM	cA	01	-19.9	0.10	3.0	UWY	U,WkI58,pCILO
22 / 9	St	cLM	cA	01	-19.2	0.05	1.0	UWY	U,WkI58,pCILO
22 /10	St	cLM	cA	01	-18.1	0.01	1.0	UWY	U,WkI58,pCILO
22 /12	St	cLM	cA	01	-19.4	0.06	2.0	UWY	U,pCILO
22 /13	St	cLM	cA	01	-18.8	0.06	2.0	UWY	U,pCILO
22 /14	St	cLM	cA	01	-18.3	0.06	3.0	UWY	U,pCILO
22 /15	St	cLM	cA	01	-17.9	0.11	2.0	UWY	U,pCILO
22 /16	St	cLM	cA	01	-18.4	0.14	1.0	UWY	U,pCILO
22 /18	St	eLM	cA	01	-19.4	0.07	3.0	UWY	U
22 /19	St	eLM	cA	01	-19.2	0.15	1.0	UWY	U
22 /20	St	eLM	cA	01	-20.2	0.09	2.0	UWY	U
22 /21	St	eLM	cA	01	-20.6	0.11	5.0	UWY	U
22 /22	St	eLM	cA	01	-19.9	0.16	2.0	UWY	U
22 /23	St	eLM	cA	01	-20.0	0.11	2.0	UWY	U
22 /24	St	eLM	cA	01	-20.1	0.20	2.0	UWY	U
22 /25	St	eLM	cA	01	-20.1	0.13	1.0	UWY	U

Sample Application of the NRL/FAA Data Base.

Modern Data for LWC > .875 g/m^3 (Column 4 of the Army Icing Test Matrix) in the Altitude Interval of 0-10,000 ft AGL.

File/Rec	Cloud Type	Geog Loc.	Air Mass	Month of Yr	OAT degC	LWC g/m^3	Data Miles	Data Source	Weather Situation
17 /36	Cu	AST	mP	05	-4.6	0.90	1.0	MRI	EWPgAHc
26 / 6	CuOr	MCC	mP	02	-8.1	0.89	0.6	UWY	Ua2FCf&WkLc
26 /15	OrCu	BLU	m	12	-6.4	1.70	2.0	UWYO	Ua*1-2FCf;SrCv
26 /47	OrCu	BLU	m	12	-13.2	0.89	2.0	UWYO	Ua*1-2FCf
27 /25	CuOr	MCC	mP	02	-8.0	1.05	1.0	UWY	Ua2FCf&WkLc
27 /36	CuOr	MCC	mP	02	-8.6	0.88	0.8	UWY	Ua2FCf&WkLc
27 /39	CuOr	MCC	mP	02	-8.8	1.08	2.0	UWY	Ua2FCf&WkLc
27 /40	CuOr	MCC	mP	02	-8.6	1.30	0.6	UWY	Ua2FCf&WkLc
27 /42	CuOr	MCC	mP	02	-8.5	0.95	1.0	UWY	Ua2FCf&WkLc
27 /45	CuOr	MCC	mP	02	-8.9	1.02	2.0	UWY	Ua2FCf&WkLc
27 /54	CuOr	MCC	mP	02	-8.3	1.09	2.0	UWY	Ua2FCf&WkLc
28 / 3	CuOr	MCC	mP	02	-8.5	0.97	2.0	UWY	Ua2FCf&WkLc
28 / 6	CuOr	MCC	mP	02	-8.7	0.96	0.9	UWY	Ua2FCf&WkLc
28 /10	CuOr	MCC	mP	02	-6.5	0.91	0.9	UWY	Ua2FCf&WkLc
28 /22	CuOr	MCC	mP	02	-8.0	1.10	2.0	UWY	Ua2FCf&WkLc
29 /21	CuOr	MCC	mP	02	-7.9	1.25	1.0	UWY	Ua*2FWkCf
29 /27	CuOr	MCC	mP	02	-7.0	1.30	2.0	UWY	Ua*2FWkCf
29 /33	CuOr	MCC	mP	02	-7.7	1.10	1.0	UWY	Ua*2FWkCf
29 /35	CuOr	MCC	mP	02	-7.3	1.05	1.0	UWY	Ua*2FWkCf
30 /50	CuOr	MCC	c?	03	-10.6	1.20	4.0	UWY	*1AFmCf
30 /52	CuOr	MCC	c?	03	-10.5	1.10	5.0	UWY	*1AFmCf
30 /54	CuOr	MCC	c?	03	-10.7	1.10	1.0	UWY	*1AFmCf
31 / 2	CuOr	MCC	c?	03	-10.0	1.30	6.0	UWY	*1AFmCf
31 / 4	CuOr	MCC	c?	03	-10.6	1.30	2.0	UWY	*1AFmCf
31 / 6	CuOr	MCC	c?	03	-11.7	1.40	3.0	UWY	*1AFmCf
31 /10	CuOr	BLU	c?	03	-11.9	1.00	1.0	UWY	*1AFmCf
31 /17	CuOr	BLU	c?	03	-12.4	1.10	1.0	UWY	*1AFmCf
35 / 5	Cu	W72	Mc	03	-5.7	1.20	0.3	NRL	LeCvO GulfStream
35 /12	Cu	W72	Mc	03	-6.4	1.10	0.5	NRL	LeCvO GulfStream
35 /23	Cu	W72	Mc	03	-7.0	1.00	0.2	NRL	LeCvO GulfStream
35 /24	Cu	W72	Mc	03	-7.0	0.90	0.2	NRL	LeCvO GulfStream
35 /25	Cu	W72	Mc	03	-7.0	1.00	0.4	NRL	LeCvO GulfStream
35 /26	Cu	W72	Mc	03	-7.0	0.90	0.2	NRL	LeCvO GulfStream
35 /29	Cu	W72	Mc	03	-7.5	1.00	1.0	NRL	LeCvO GulfStream
40 /10	Cu	SEA	mP	12	-3.0	1.00	0.2	UWSH	0-.1ACfSu@Fl
40 /16	Cb	SEA	mP	12	-1.0	1.10	1.0	UWSH	0-.1ACfSu@Fl
40 /30	Cu	HQM	mP	01	-4.3	1.10	3.0	UWSH	Ud@CfSu@Fl,&3aRb
40 /38	Sc	237	mP	02	-4.5	0.91	1.0	UWSH	1W&ASf,&2-3E&ACf
42 /21	CuCb	OLM	mP	04	-8.7	0.93	1.0	UWSH	Ua2-3FFmCf&0f
42 /22	CuCb	OLM	mP	04	-4.8	1.20	3.0	UWSH	Ua2-3FFmCf&Uf

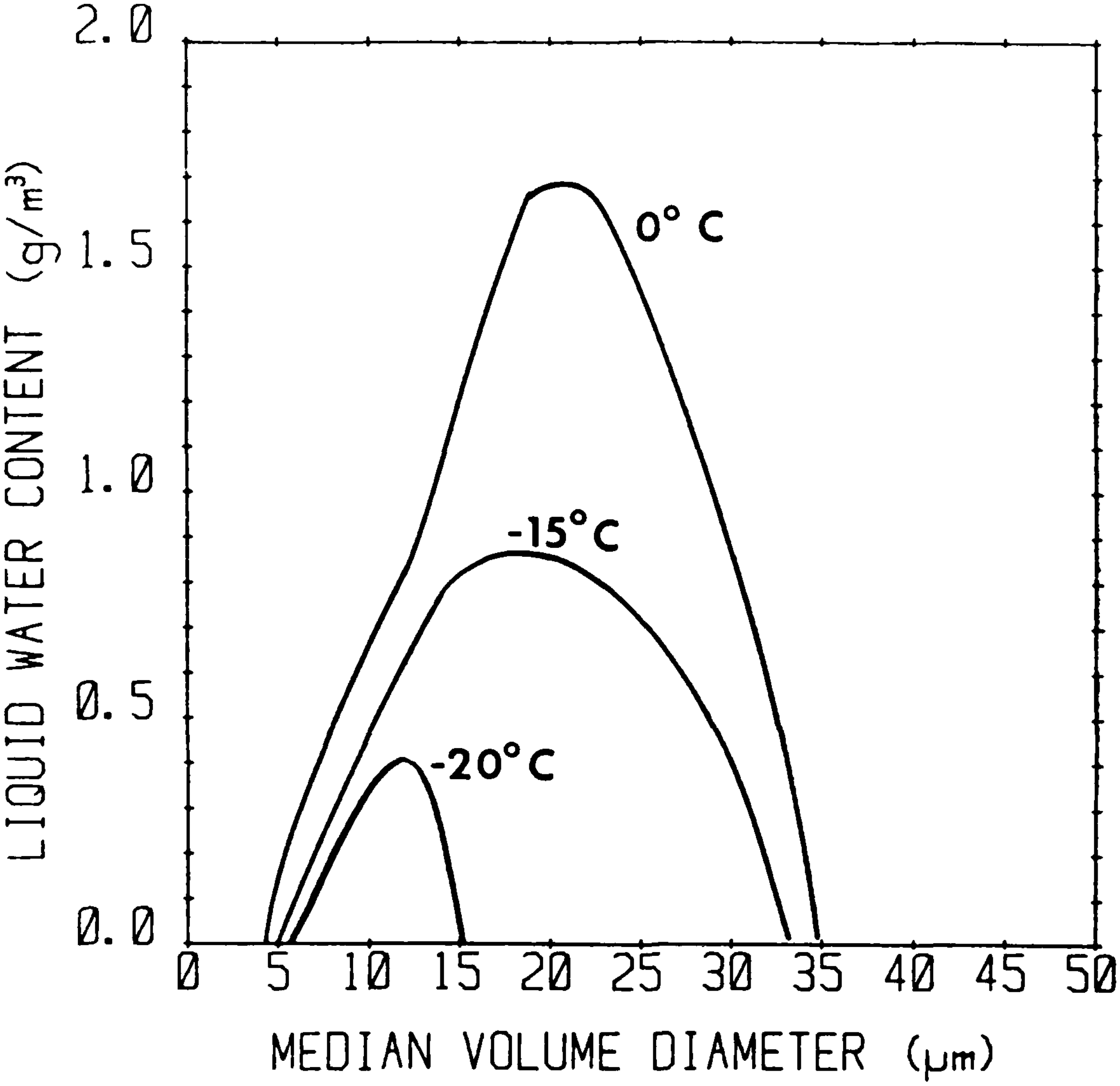


FIGURE 47. APPROXIMATE EXTREME VALUES OF LWC AND MVD COMBINATIONS OBSERVED IN SUPERCOOLED CLOUDS AT ALTITUDES UP TO 10,000 FT AGL. The curved lines here represent the approximate extreme values of LWC and MVD observed in any supercooled cloud icing event up to 10,000 ft AGL and up to the temperatures indicated.

Sample Application of the NRL/FAA Data Base.

Sample Application of the NRL/FAA Data Base.

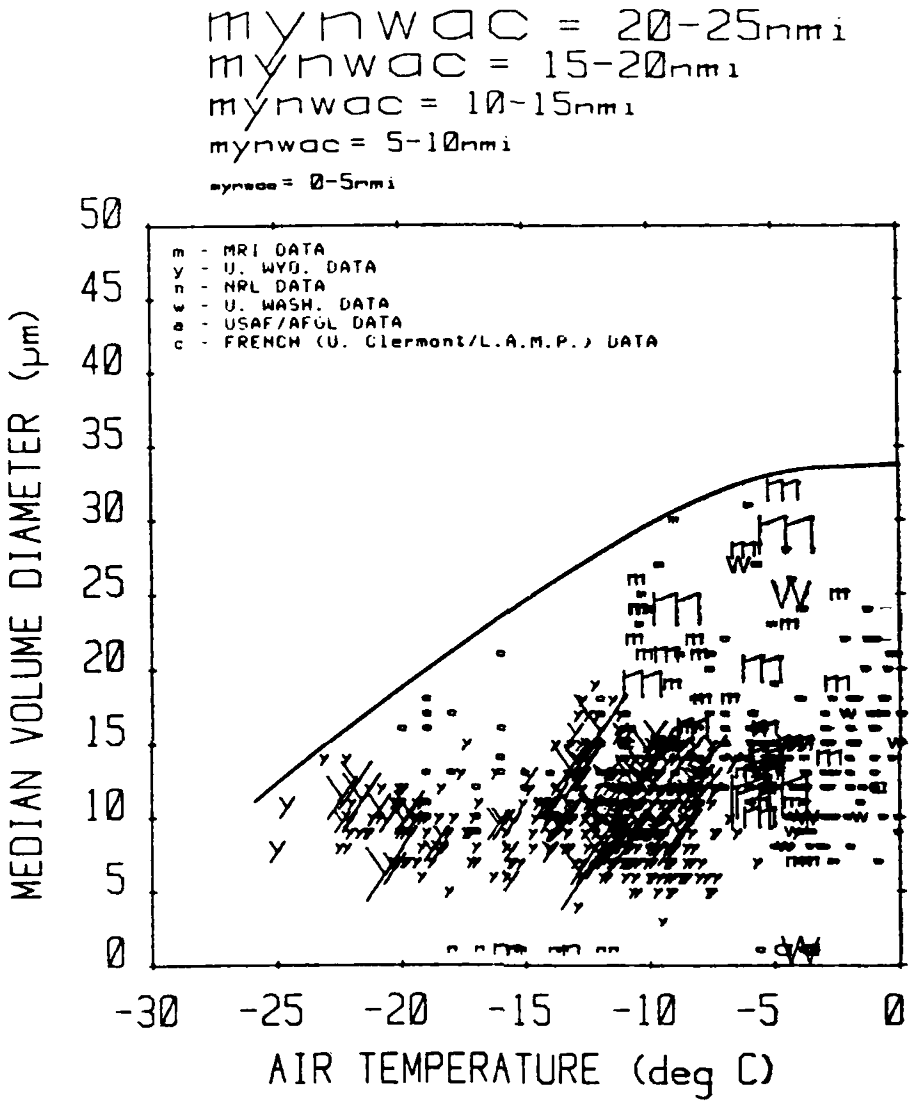


FIGURE 38. SCATTERPLOT OF MVD VS. OAT FOR MODERN DATA FROM SUPERCOOLED LAYER CLOUDS (St, Sc, Ns, As, Ac) UP TO 10,000 FT AGL. The various plotting symbols represent different data sources as indicated in the key. The size of each symbol is proportional to its statistical weight (i.e., the observed horizontal extent of the associated icing event) as shown by the scale above the graph. The center of each symbol corresponds to the average (and approximately constant) value of MVD and OAT observed during the icing event. The solid line bounding the data points represents the apparent upper limit to MVD as a function of temperature for supercooled layer clouds below 10,000 ft AGL. The position of the line at temperatures above -15°C is based on the maximum MVDs in the modern data only, but below -15°C the line is based on maximum MVDs from both the NACA and modern data sets. The data points plotted at 1 μm MVD are those for which the MVD values are actually unknown. A total of 2660 data miles is represented in this graph.

Sample Application of the NRL/FAA Data Base.

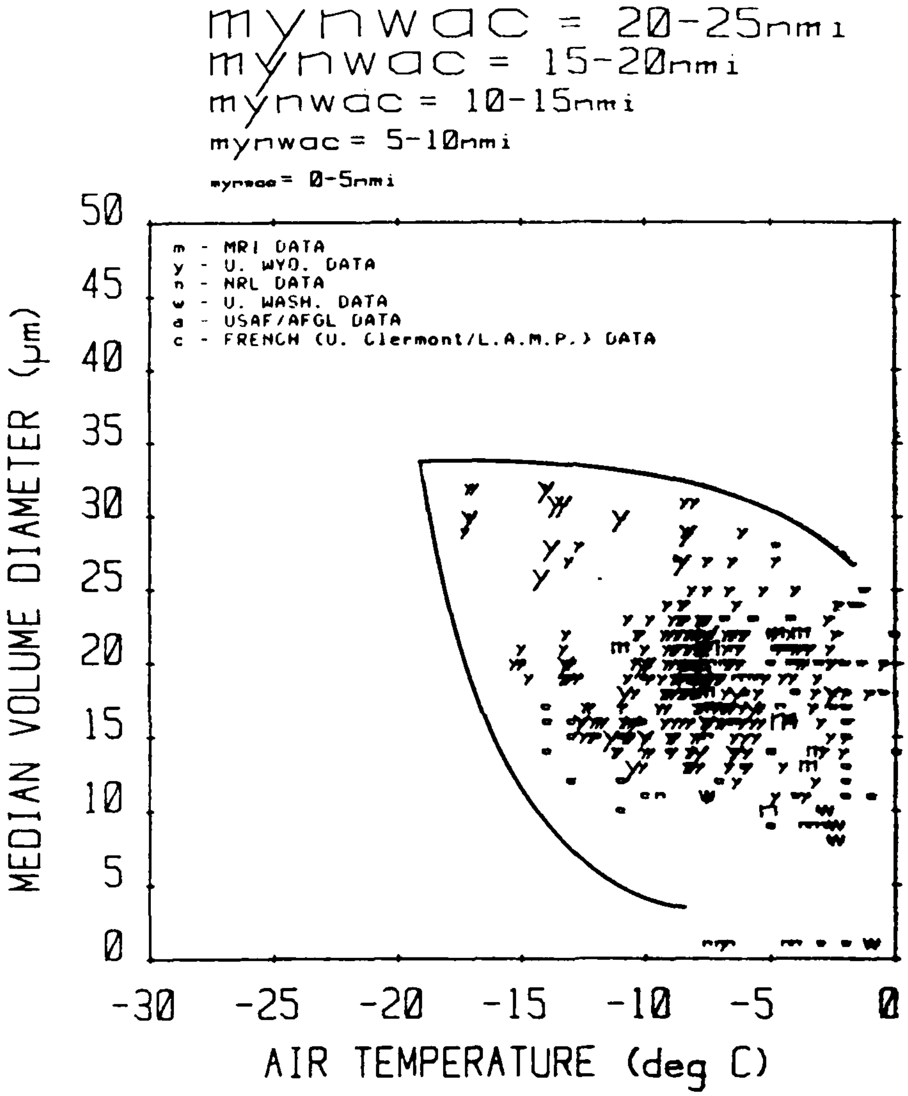


FIGURE 40. SCATTERPLOT OF MVD VS. OAT FOR MODERN DATA FROM SUPERCOOLED CONVECTIVE CLOUDS (Cu, Cb) UP TO 10,000 FT AGL. The various plotting symbols represent different data sources as indicated in the key. The size of each symbol is proportional to its statistical weight (i.e., the observed horizontal extent of the associated icing event) as shown by the scale above the graph. The center of each symbol corresponds to the average (and approximately constant) value of MVD and OAT observed during the icing event. The solid line bounding the data points represents the apparent upper and lower limit to MVD as a function of temperature for supercooled convective clouds below 10,000 ft AGL. The position of the line is based on extreme MVD values in both the NACA and modern data sets. The data points plotted at 1 μm MVD are those for which the MVD values are actually unknown. A total of 980 data miles is represented in this graph.

PART III

LIST OF INVITEES

LIST OF INVITEES AND DISTRIBUTION LIST

SECOND TRI-SERVICE CLOUD MODELING WORKSHOP

26-27 JUNE 1984

DEPARTMENT OF DEFENSE

Office of the Under Secretary of Defense,
  Research and Engineering
Office of Environmental and Life Sciences
Room 3D129
The Pentagon
Washington, D.C. 20301
    Attn: CAPT. Edward Harrison

Defense Advanced Research Projects Agency/DEO
1400 Wilson Boulevard
Arlington, VA 22209
    Attn: Lt. Col. R.P. Benedict
          Dr. Louis C. Marquet, Room 911

Defense Advanced Research Projects Agency/STO
1400 Wilson Boulevard
Arlington, VA 22209
    Attn: Col. Wesley Kurowski, Room 941
          Lt. Col. Howard Stears
          Dr. Anthony J. Tether

Defense Advanced Research Projects Agency/TTO
1400 Wilson Boulevard
Arlington, VA 22209
    Attn: Mr. John Hanson

Joint Cruise Missiles/ASG
Washington, DC 20363
    Attn: Lt. Col. M.I. Bloom, Room 12E45

NORAD/J3W
Peterson Field, CO 80914
    Attn: Maj. George Davenport

Department of Defense, Continued

Defense Nuclear Agency
Washington, DC 20305
Attn: Maj. Martin R. Allerding, RAAE
Mr. Patrick A. Crowley, RAAE
Dr. H.C. Fitz, Jr., RAAE
Mr. Peter W. Lunn, RAAE
Lt. Col. William J. McKechney, RAAE
Dr. Randy Rohr, Aerospace Systems
Mr. Kenneth Schwartz
Dr. Jim Sommers, Aerospace Systems
Lt. Col. Gilbert W. Ullrich, RAAE
Dr. Leon Wittwer, RAAE

U.S. ARMY

Headquarters, Department of the Army
Chemical Engineering
Pulaski Building
20 Massachusetts Avenue, N.W.
Washington, DC 20314
Attn: Dr. Richard Gomez, DAEN-RDM, Room 6203

U.S. Army Engineer Topographic Laboratory
ETL-GS-A
Fort Belvoir, VA 22060
Attn: Dr. Paul C. Dalrymple

Commander/Director
USA Atmospheric Sciences Laboratory
White Sands Missile Range, NM 88002
Attn: Dr. Elton P. Avara
Dr. Andreas Goroch
Dr. Melvin C. Heaps

BMD Syscom
106 Wynn Drive
Huntsville, AL 35807
Attn: John W. Bowman

DARCOM
Harry Diamond Laboratory
2800 Powder Mill Road
Adelphi, MD 20783
Attn: Dr. Zoltan G. Sztankay, DELHD-RT-GB

U.S. Army Missile Command
Redstone Arsenal, AL 35898
Attn: Mr. George P. Drake, DRSMI-RAS
Dr. Oskar M. Essenwanger, DRSMI-RRA

U.S. Army, Continued

U.S. Army Engineer Topographic Lab
ETL-GS-A
Fort Belvoir, VA 22060
Attn: Dr. Donald Dery

U.S. Army Missile Command
P.O. Box 1500
Huntsville, AL 35809
Attn: Mr. Al Carmichael, BMD ATC-T
Dr. W. Davies
Mr. Jerry Hagood, Chief, DARPA/STO Project Office

Cold Regional Research and Evaluation Laboratory
Geophysical Sciences Branch
CRREL-RG
Hanover, NH 03755
Attn: Dr. Roger Berger

Atmospheric Sciences Laboratory
Directed Energy Branch
White Sands Missile Range, NM 80022
Attn: Mr. Tom Hall

U.S. Army Combined Arms Center
ATZL-CAC-11E
Fort Leavenworth, KS 66027
Attn: Mr. Elbert S. Kennedy

U.S. NAVY

U.S. Naval Air Development Center
Warminster, PA 18974
Attn: Dr. Alan H. Blumenthal, Code 3011
Mr. Michael R. Hess, Code 3011

Naval Air Systems Command
Washington, DC 20361
Attn: Mr. Barry Dillon, Code 340
Dr. Paul Twitchell, AIR 330-G
Dr. Paul Wyman, AIR 5493

Naval Environmental Prediction Research Facility
Naval Postgraduate School Annex
Monterey, CA 93943
Attn: CDR. Donald Hinsman
Mr. Roland E. Nagle
Dr. Paul M. Tag

U.S. Navy, Continued

Naval Observatory
OPNAV 952D
34th and Massachusetts Avenue, N.W.
Washington, DC 20390
Attn: CAPT. Carl W. Hoffman

Naval Ocean Systems Center
San Diego, CA 92152
Attn: Virgil R. Noonkester
Dr. Juergen Richter
Dr. Larry B. Stotts, Code 8114

Office of Chief of Naval Operations
34th and Massachusetts Avenue, N.W.
Washington, DC 20390
Attn: CDR. Rene E. Gonzalez, Jr., OP-952
Dr. Richard W. James, OP-952D1

Office of Chief of Naval Operations
Washington, DC 20350
Attn: CDR. Tom Piwowar, OP-986

Office of Naval Research
800 North Quincy Street
Arlington, VA 22217
Attn: Mr. Robert Abbey, Code 422MM
Dr. William F. Cross, Code 422PO
Dr. Douglas J. DePriest
Mr. James H. Hughes, 422AT
Dr. Edward Wegman, Code 411
Dr. Alan Weinstein

Naval Research Laboratory
Washington, DC 20395
Attn: Dr. Timothy Coffey
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Dr. Richard K. Jeck, Code 4113
Dr. Vince Noble, Code 7910
Dr. Lothar Ruhnke
R. Steinberg, Code 6509
Dr. Edward J. Stone, Code 6520

Naval Sea Systems Command, PMS-405
Washington, DC 20362
Attn: LCDR Stanley Grigsby, Code 24
Mr. Ralph Rudkin
Mr. A.L. Stoessel,

U.S. Navy, Continued

Naval Space Command
Dahlgren, VA 22448
Attn: CAPT. M.B. Hollinger

Naval Surface Weapons Center
Dahlgren, VA 22448
Attn: Mr. Roger W. Carson, K-44
Ms. Kathleen J. Fairfax, K-44
Ralph J. Fallin
Mr. A. Hershman, K-44
Susan L. Masters, K-44
Ms. Dorritt Redding

Naval Surface Weapons Center
White Oak
Silver Spring, MD 20918
Attn: Barton D. Billard
W.E. Caswell, R-42, 90-001D
Robert Cawley
Gee-In Goo
Ms. Zarak Hanks, K-44, 1200
Mr. Abraham Hirschman
Dr. Barry S. Katz
Dr. Bernard V. Kessler, R-42
Carl W. Larson
Mr. Donald E. Matlack
Martha Melnik, R-42
Mr. Spyros K. Petropoulos

Commander Naval Weapons Center
China Lake, CA 93555
Attn: Mr. Edward J. Bevan, Code 3912
Donald A. Kappelman, Code 39403
Stuart H. Breil

Strategic Systems Project Office
Washington, DC 20376
Attn: Mr. Jay Berkowitz
Mr. Richard Sokol

Executive Officer
Fleet Numerical Oceanography
Monterey, CA 93943

Headquarters, Air Weather Service, Det. 1
The Pentagon
Washington, DC 20330
Attn: Lt. Col. Randolph W. Ashby
Capt. Lauraleen O'Connor

AIR FORCE

Headquarters, Air Weather Service
Scott Air Force Base, IL 62225
Attn: Maj. Marvin G. Coleman, DNXA
Lt. Col. Roy E. Harriman, DNXA
Col. Haugh, DN
Lt. Col. Edward F. Kolczynski, DNXA
Maj. Douglas Moore, DNXA
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Air Force Air Weather Service
Global Weather Center
Offut Air Force Base, NB 68113
Attn: Lt. Col. William Cox, TS
Lt. Col. Morse, DOX

Air Force Armament Laboratory
Eglin Air Force Base, FL 32542
Attn: Vito Marinelli

Air Force BMO/WE
Norton Air Force Base, CA 92403
Attn: Capt. George Fisher

Air Force CMD/SA
Kirtland Air Force Base, NM 87117
Attn: Lt. Brent J. Cote
Dr. Bruno Manz

U.S. Air Force Environmental Technical Applications Center
Scott Air Force Base, IL 62225
Attn: Maj. Al Boehm
Dr. Patrick J. Breitling, CCN
Lt. Col. Peter J. Havanac, DN
Lt. Col. Pershing Hicks, Jr., DN
Lt. Col. Walt Meyer

Air Force 1st Weather Wing/CV
Hickam Air Force Base, HI 96853
Attn: Col. Paul Try

Air Force 4th Weather Wing
Peterson Air Force Base, CO 80914
Attn: Maj. George Davenport, DN

U.S. Air Force, Continued

Air Force Geophysical Laboratory
Hanscom Air Force Base, MA 01731
Attn: Dr. Arnold Barnes, LYC
Mr. James T. Bunting, LYS
Dr. Robert Fenn, OPA
Dr. John Garing, OP
Mr. Donald Grantham, LYT
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Dr. McClatchey, LY
Dr. Brian Sandford, OPR
Mr. John H. Schummers, LSA
Eric Shettle, OPA

Air Force Institute of Technology/CIRF (ATC)
Wright-Patterson Air Force Base, OH 45433
Attn: Arthur C. Meade

Air Force Office of Scientific Research
Bolling Air Force Base, DC 20332
Attn: Lt. Col. Jerry Dittberner

Headquarters, Air Force Space Command
Peterson Air Force Base, CO 80914
Attn: Capt. David Dyche, XPSD

U.S. Air Force Space Division
P.O. Box 92960
Worldway Postal Center
Los Angeles Air Force Station, CA 90009
Attn: Capt. Elizabeth Ayers, WE
Edmund D. Daszewski, WE
Lt. Col. Thomas Dopplick, WE
Mark W. Lindsey
Lt. Col Larry Mendenhall, DAAX
Todd M. Niepke
Lt. Col. Edward M. Tomlinson, DAAX
Maj. Lloyd Young, YNS

Air Force Space Technology Center
Kirtland Air Force Base, NM 87117
Attn: Maj. Luces, WE

Headquarters, Strategic Air Command
Offutt Air Force Base, NB 68113
Attn: Maj. Larry Bailey
Maj. Buchanan, DOWA
Capt. Rodney Liesveld, SXRS
Maj. Jeffrey S. Schleher, DOWA

U.S. Air Force, Continued

Air Force Studies and Analysis
Washington, DC 20330
Attn: Lt. Col. Roger Christensen, SAZ
Lt. Col Thomas E. Moriarty, SAZ

Headquarters, Air Force Systems Command
Andrews Air Force Base, MD 20334
Attn: J. Anderson
Lt. Col Wallace H. Chaplin
Capt. G. Anderson White, WER

Air Force Weapons Laboratory
Kirtland Air Force Base, NM 87117
Attn: Lt. Col. Vernon L. Bliss, WE
Col Gilbert, AR3
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Alfred L. Sharp, NTAT
Darrell Spreen, ARE

Wright Aeronautical Laboratory
Wright-Patterson Air Force Base, OH 45433
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Maj. Wayne Harper, WE
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Drexel G. Waggoner, AARI-3

OTHER GOVERNMENT

NASA Headquarters
Washington, DC 20546
Attn: Dr. Robert Schiffer, Code EE
Dr. Shelby Tilford

NASA Ames Research Center - Unclassified Version Only
Space Science Division 245-3
Mountain View, CA 94035
Attn: Dr. Edwin Danielsen

NASA Goddard Space Flight Center
Greenbelt, MD 20771
Attn: Dr. Albert Arking
Dr. Robert Fraser
Dr. Paul Hwang - Unclassified Version Only
Dr. Joanne Simpson, Code 914

Other Government, Continued

NOAA Aeronomy Lab/ERL
325 Broadway
Boulder, CO 80303
Attn: Dr. Freeman Hall, R4X2

NOAA/NESDIS
Federal Office Building 4
Suitland and Silver Hill Roads
Washington, DC 20233
Attn: Dr. Herbert Jacobowitz, ASB
Dr. L.L. Stowe
Dr. Harold Yates

NOAA Air Resources Laboratory
Eighth Floor
6010 Executive Building
Rockville, MD 20852
Attn: Dr. Lester Machta

NOAA National Climate Program
Room 108
11400 Rockville Pike
Rockville, MD 20852
Attn: Mr. Martin C. Yerg

INDUSTRY

Aerodyne Research
45 Manning Road
Billerica, MA 01821
Attn: Dr. Morton Camac
Dr. H.J. Caulfield
Dr. Robert B. Lyons

Aerojet Electrosystems
1100 West Hollyvale Street
P.O. Box 296
Azusa, CA 91702
Attn: Mr. Alain L. Fymat
Mr. Bernard Lichtenstein
Ms. Rosia Y. Pan, Dept. 4211, Bldg. 160
Mr. Amiel Shulsinger
Ms. Edna M. Sugihara
Ms. Ellen S. Thomas

Aerojet General Corporation
P.O. Box 13222
Sacramento, CA 95813
Attn: Mr. Thomas G. Lee

Industry, Continued

AeroMet Inc.
P.O. Box 701767
Tulsa, Oklahoma 74170
Attn: Mr. Ed Gibeau

Analytics, Scientific and Operations Analysis Group
7680 Old Springhouse Road
McLean, VA 22102
Attn: Dr. Kenneth D. Shere

Atlantic Analysis Corporation
5 Koger Executive Center
Suite 219
Norfolk, VA 23502
Attn: Mr. Roger S. Staff

Atmospheric and Environmental Research Inc.
840 Memorial Drive
Cambridge, MA 02139
Attn: Mr. Ronald G. Isaacs

Boeing Aerospace Company
P.O. Box 3707
Seattle, WA 98124
Attn: Mr. Richard Geer
Dr. Martin Savol

Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124
Attn: Mr. Tom Sangston, Mail Stop 8H37

Calspan Corporation
P.O. Box 400
Buffalo, NY 14225
Attn: Dr. Paul Marrone

Control Data Corporation
Research Division
P.O. Box 1249
Minneapolis, MN 55440
Attn: Mr. Greg Nastrom

Environmental Research Institute of Michigan
P.O. Box 618
Ann Arbor, MI 48107
Attn: Dr. Anthony J. Larocca

Industry, Continued

General Dynamics
Mail Zone 2814
P.O. Box 748
Fort Worth, TX 76101
Attn: Mr. Tommy R.R. Augustsson
Mr. John A. Guinn, Jr.

General Dynamics
P.O. Box 2507
Pomona, CA 91769
Attn: Mr. Richard M. Pietrasz/MZ 600-7

General Dynamics
Corvair Division
P.O. Box 80847
San Deigo, CA 92138
Attn: Mr. J.S. Toor, MZ 41-6850

General Electric
Aerospace Electronic Systems Department
French Road
Utica, NY 13503
Attn: Mr. Phillip W. Kane, Mail Drop 39

General Electric - AEBG
1 Neumann Way
Cincinnati, OH 45215
Attn: Mr. S.D. Bertke, Mail Drop J-185

General Electric - AESD
901 Broad Street
Utica, NY 13503
Attn: Mr. Lorne H. Ford, Mail Drop 900
Mr. Philip W. Kane, Mail Drop 900

General Electric Company
P.O. Box 4840
Syracuse, NY 13221
Attn: Mr. Edwin L. Post, CSP-5, Room G7

General Motors Research Lab
Physics Department
Warren, MI 48090
Attn: Dr. Ruth Reck

General Research Corporation
Westgate Research Park
7655 Old Springhouse Road
McLean, VA 22102
Attn: Mr. John L. Gilbert
Mr. Robert Poppe

Industry, Continued

General Research Corporation
P.O. Box 6770
Santa Barbara, CA 93111
Attn: Mr. Richard Rein
Mr. Tim Sullivan

Grumman Aerospace Corporation
R&D Center, Plant 26
Bethpage, NY 11714
Attn: Mr. Gil Kelley, MS B06-04
Dr. Jerry Krassner
Dr. John E.A. Selby

Honeywell EOD
2 Forbes Road
Lexington, MA 02173
Attn: Mr. Raymond Gelinas

Honeywell, Inc.
Minneapolis, MN 55440
Attn: Dr. Joseph E. Carroll, MN 17-2328

IRT Corporation
6800 Poplar Place
McLean, VA 22101
Attn: Dr. David M. Harris
Mr. David P. Woodall

ITT Avionics Division
390 Washington Avenue
Nutley, NJ 07110
Attn: Mr. Robert J. Kraushaar
Mr. Kevin B. Ward

Kaman Sciences
1500 Garden-of-the-Gods Road
Colorado Springs, CO 80933
Attn: Mr. Jerry L. Harper
Mr. Jacob J. Hess
Mr. Wayne J. Young

Lockheed Missiles and Space Company
0/92-20, B/205
3251 Hanover Street
Palo Alto, CA 94304
Attn: Mr. Scott Claflin
Dr. George Gal
Mr. Norman Kulgein
Dr. Alexander Maksymowicz
Mr. Wayne Rudolf
Mr. T. Winarske

Industry, Continued

Lockheed Missiles and Space Company
P.O. Box 56
Sunnyvale, CA 94086
Attn: Mr. Lee G. Dickinson, Dept. 85-72
Dr. Rich Hake, Dept. 62-23

Lockheed California Compnay
P.O. Box 551
Burbank, CA 91520
Attn: Mr. A.C. Brown

Loton Research
3377 North Torrey Pines Court
La Jolla, CA 92037
Attn: Mr. David M. Zimmerman

McDonnell Douglas
A3-232-13-3
McDonnell Douglas Astronautics Company
5301 Bolsa Avenue
Huntington Beach, CA 92647
Attn: Mr. Robert A. Willett

Ontar Corporation
129 University Road
Brookline, MA 02146
Attn: Mr. John W. Schroeder

The Optical Sciences Company
P.O. Box 1329
Placentia, CA 92670
Attn: Dr. David Fried
Dr. David L. Hench

The Optical Sciences Company
8301 Greensboro Drive
McLean, VA 22102
Attn: Dr. Thomas F. Wiener

OptiMetrics Inc.
P.O. Box 7766
Ann Arbor, MI 48107
Attn: Mr. William O. Gallery
Dr. Robert E. Meredith
Mr. Merle J. Persky
Mr. Frederick G. Smith

Industry, Continued

Pacific-Sierra Research Corporation
Suite 1100
1401 Wilson Boulevard
Arlington, VA 22209
Attn: Dr. Ronald N. DeWitt

Pacific-Sierra Research Corporation
12340 Santa Monica Boulevard
Los Angeles, CA 90025
Attn: Mr. Alan Shapiro

Perkin-Elmer Company
100 Wooster Heights Road
Danbury, CT 06810
Attn: Dr. Robert Arguello, MS 845

PhotoMetrics, Inc.
4 Arrow Drive
Woburn, MA 01801
Attn: Dr. Irving L. Kofsky

Photon Research Associates
2223 Avenida De La Playa
Suite 301
La Jolla, CA 92037
Attn: Dr. David Anding
Dr. William Cornette

Physical Sciences Inc.
P.O. Box 3100
Research Park
Andover, MA 01810
Attn: Dr. Guy Weyl

Radiation Research
3550 Hulen Street
Fort Worth, TX 76107
Attn: Dr. M.B. Wells

Rockwell International
11642 Wallingsford Road
Los Alamitos, CA 90720
Attn: Mr. Michael F. Sentovich

SRI International
333 Ravenswood Avenue
Menlo Park, CA 94061
Attn: Dr. J.H. Allen
Mr. John D. Malick
Mr. Richard H. Monahan, Room AH-157

Industry, Continued

Science Applications Inc.
P.O. Box 1303
McLean, VA 22101
Attn: Dr. John Connolly

Science Applications Inc.
505 Marquette, N.W.
Albuquerque, NM 87102
Attn: Dr. James L. Griggs, Jr.
Mr. Ronald J. Nelson

Science Applications Inc.
P.O. Box 2351
La Jolla, CA 92083
Attn: Mr. Dan Hamlin

Science Applications Inc.
1010 Woodman Avenue
Dayton, OH 45432
Attn: Mr. Bob Turner

Scientific Simulation Inc.
P.O. Box 9331
Albuquerque, NM 87119
Attn: Dr. L.R. Ebbesen
Mr. Don C. Fronterhouse

Spectral Sciences Inc.
111 South Bedford Street
Burlington, MA 01803
Attn: Dr. Lawrence Bernstein
Dr. David C. Robertson

Systems and Applied Sciences Corporation
5809 Annapolis Road
Hyattsville, MD 20784
Attn: Dr. P.K. Bhartia - Unclassified Version Only

Systems and Applied Sciences Corporation
109 Massachusetts Avenue
Lexington, MA 02173
Attn: Dr. Ralph Shapiro
Mr. C.N. Touart

TASC
1 Jacob Way
Reading, MA 01867
Attn: Dr. Robert F. Brammer
Dr. Paul Janota

Industry, Continued

TASC
8301 Greensboro Drive
McLean, VA 22102
Attn: Dr. Thomas Wiener

TRW
One Space Park
Building 82/1710
Redondo Beach, CA 90278
Attn: Mr. Bill Momary

Teledyne Brown Engineering
300 S. Parkman Drive
MS-19
Huntsville, AL 35807
Attn: Mr. Robert A. Pilgrim
Mr. Mike Scarboro

Titan Systems
P.O. Box 12139
La Jolla, CA 92037
Attn: Jeffrey J. Puschell

Verac, Inc.
2901 Juan Tabo, N.E.
Suite 235
Albuquerque, NM 87112
Attn: Mr. Joel S. Davis
Mr. Jack Davis
Mr. Bryan Thompson

Verac, Inc.
10601 Lomas Boulevard, N.E.
Suite 115
Albuquerque, NM 87112
Attn: Dr. T.M. Bomber

Visidyne
5 Corporate Place
South Bedford Street
Burlington, MA 01803
Attn: Dr. Charles H. Humphrey
Dr. Henry Smith

OTHER

Aerospace Corporation
2350 El Segundo Boulevard
El Segundo, CA 90009

Attn: Mr. Roy M. Chiulli
Mr. David Escoe
Mr. Eric Jensen, M1/041
Mr. Paul Kisliuk
Dr. Hugh Rugge
Dr. Fred Simmons

Colorado State University
Fort Collins, CO 80523
Attn: Dr. Tom Brubaker, Electrical Engineering Dept.
Unclassified Version Only
Prof. Thomas Vonderhaar, Atmospheric Sciences Dept.

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
Attn: Dr. Alex Goetz
Dr. E. Hinkley

Johns Hopkins (APL)
Johns Hopkins Road
Laurel, MD 20777
Attn: William J. Tropf
Randolph W. Bruns

Johns Hopkins (APL)
9713 Clocktower #202
Columbia, MD 21046
Attn: Andrew N. Vavreck

Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94550
Attn: Dr. Joseph B. Knox
Dr. M. McCracken

Los Alamos National Laboratory
International Technical Office
P.O. Box 503
Los Alamos, NM 87545
Attn: Dr. Sumner Barr
Dr. Henry G. Horak

Other, Continued

MIT Lincoln Laboratory
P.O. Box 73
Lexington, MA 02173
Attn: Dr. Herb Kleiman
Mr. John T. Prohaska, KB 237

RAND Corporation
1700 Main Street
Santa Monica, CA 90406
Attn: Mr. Ralph Huschke

Scripps Institute for Oceanography
Visibility Laboratory
University of California, San Diego
La Jolla, CA 92093
Attn: Mr. Wayne Hering, P-003
Mr. Richard W. Johnson

University of Maryland
Institute of Physical Science and Technology
College Park, MD 20742
Attn: Dr. Thomas Wilkerson

University of Washington
Seattle, WA 98195
Attn: Prof. Peter Hobbs

IDA

Dr. Ernest Bauer, STD
Mr. Lucien Biberman, STD
Dr. Erwin Kaufman, SED
Ms. Elizabeth Li
Dr. David L. Randall, SED
Dr. Robert C. Oliver, STD
Dr. Hans Wolfhard, STD

PART IV

LIST OF ATTENDEES

U.S. ARMY

Commander/Director
USA Atmospheric Sciences Laboratory
WSMR, NM 88002
Attn: Dr. Elton P. Avara

BMD Syscom
106 Wynn Drive
Huntsville, AL 35807
Attn: John W. Bowman

DARCOM
Harry Diamond Labs
2800 Powder Mill Road
Adelphi, MD 20783
Attn: Dr. Zoltan G. Sztankay, DELHD-RT-LB

U.S. Army Missile Command
Redstone Arsenal, AL 35898
Attn: Mr. George P. Drake, DRSMI-RAS
Dr. Oskar M. Essenwanger, DRSMI-RRA

U.S. NAVY

U.S. Naval Air Development Center
Warminster, PA 18974
Attn: Dr. Alan H. Blumenthal, Code 3011
Mr. Michael R. Hess, Code 3011

Naval Air Systems Command
AIR 330G
Washington, DC 20361
Attn: Dr. Paul Twitchell, AIR 330-G
Dr. Paul Wyman, AIR 5493

Naval Environmental Prediction Research Facility
24 Greenwood Vale
Monterey, CA 93943
Attn: Dr. Roland E. Nagle
Dr. Paul M. Tag

U.S. Navy, Continued

Naval Ocean Systems Center
San Diego, CA 92152
Attn: Virgil R. Noonkester

Office of Naval Research
800 North Quincy Street
Arlington, VA 22217
Attn: Douglas J. DePriest
Mr. James H. Hughes, 422AT

Naval Research Laboratory
Washington, DC 20395
Attn: Dr. John Hornstein, Code 6520
Dr. Richard K. Jeck, Code 4113
Dr. Edward J. Stone, Code 6520

Naval Sea Systems Command
Washington, DC 20362
Attn: LCDR Stanley Grigsby, PMS-405

Naval Surface Weapons Center
Dahlgren, VA 22448
Attn: Ms. Kathleen J. Fairfax
Ralph J. Fallin
Susan L. Masters, K-44

Naval Surface Weapons Center
White Oak
Silver Spring, MD 20918
Attn: Barton D. Billard
W.E. Caswell, R-42, 90-001D
Robert Cawley
Ms. Zarak Hanks, K-44, 1200
Dr. Bernard V. Kessler, R-42
Carl W. Larson
Martha Melnik, R-42

Commander Naval Weapons Center
China Lake, CA 93555
Attn: Mr. Edward J. Bevan, Code 3912
Donald A. Kappelman, Code 39403

AIR FORCE

Headquarters, Air Weather Service
Det. 1
The Pentagon
Washington, DC 20330
Attn: Lt. Col. Randolph W. Ashby
Capt. Lauraleen O'Connor

U.S. Air Force, Continued

U.S. Air Force Environmental Technical Applications Center
Scott Air Force Base, IL 62225
Attn: Dr. Patrick J. Breitling, CCN
Lt. Col. Pershing Hicks, Jr., DN

Air Force Geophysical Laboratory
Hanscom Air Force Base, MA 01731
Attn: Mr. James T. Bunting, LYS
Dr. Robert Fenn, OPA
Mr. Donald Grantham, LYT
Mr. Irving I. Gringorten, LYT,H
Mr. John H. Schummers, LSA

U.S. Air Force Space Division
P.O. Box 92960
Worldway Postal Center
Los Angeles Air Force Station, CA 90009
Attn: Edmund D. Daszewski, WE
Mark W. Lindsey
Todd M. Niepke
Lt. Col. Edward M. Tomlinson, DAAX

Headquarters, Air Force Systems Command
Andrews Air Force Base, MD 20334
Attn: Capt. G. Anderson White, WER

Air Force Weapons Laboratory
Kirtland Air Force Base, NM 87117
Attn: Lt. Col. Vernon L. Bliss, WE
Alfred L. Sharp, NTAT

Air Force Global Weather Central/TSIT
Offutt Air Force Base, NE 68113
Attn: Lt. Col. William M. Cox

Wright Aeronautical Laboratory
Wright-Patterson Air Force Base, OH 45433
Attn: Capt Michael D. Abel, WEA
Drexel G. Waggoner, AARI-3

OTHER GOVERNMENT

National Climate Program
NOAA
Room 108
11400 Rockville Pike
Rockville, MD 20852
Attn: Martin C. Yerg

INDUSTRY

Aerodyne Research
45 Manning Road
Billerica, MA
Attn: Dr. Robert B. Lyons

Aerojet Electrosystems
1100 West Hollyvale Street
P.O. Box 296
Azusa, CA 91702
Attn: Alain L. Fymat
Edna M. Sugihara

Aerojet General Corporation
P.O. Box 13222
Sacramento, CA 95813
Attn: Thomas G. Lee

Aerospace Corporation
2350 El Segundo Boulevard
El Segundo, CA 90009
Attn: Roy M. Chiulli

Aerospace Corporation
Mail Station M1/041
P.O. Box 92957
Los Angeles, CA 90009
Attn: Dr. Eric B. Jensen

Atmospheric Sciences BV/NOAA
NESDIS
5001 Silver Hill Road
Washington, DC 20233
Attn: Dr. Herbert Jacobowitz

Atlantic Analysis Corporation
5 Koger Executive Center
Suite 219
Norfolk, VA 23502
Attn: Roger S. Staff

General Dynamics
Mail Zone 2814
P.O. Box 748
Fort Worth, TX 76101
Attn: Tommy R.R. Augustsson

General Dynamics
P.O. Box 2507
Pomona, CA 91769
Attn: Richard M. Pietrasz/MZ 600-7

Industry, Continued

General Electric
Aerospace Electronic Systems Department
French Road
Mail Drop 39
Utica, NY 13503
Attn: Phillip W. Kane

General Research
Westgate Research Park
McLean, VA 22102
Attn: John L. Gilbert

Grumman Aerospace
Plant 26
R&D Center
Bethpage, NY 11714
Attn: Dr. Jerry Krassner

ITT Corporation
390 Washington Avenue
Nutley, NJ
Attn: Mr. Robert J. Kraushaar

Kaman Sciences
1500 Garden-of-the-Gods Road
Colorado Springs, CO 80933
Attn: Mr. Jerry L. Harper

Lockheed
0/92-20, B/205
3251 Hanover Street
Palo Alto, CA 94304
Attn: Dr. George Gal
Alexander Maksymowicz

Lockheed Missiles and Space Company
P.O. Box 56
Department 85-72
Building 154
Sunnyvale, CA 94806
Attn: Mr. Lee G. Dickinson

Loton Research
3377 North Torrey Pines Court
La Jolla, CA 92037
Attn: David M. Zimmerman

Industry, Continued

McDonnell Douglas
A3-232-13-3
McDonnell Douglas Astronautics Company
5301 Bolsa Avenue
Huntington Beach, CA 92647
Attn: Robert A. Willett

Ontar Corporation
129 University Road
Brookline, MA 02146
Attn: Mr. John W. Schroeder

The Optical Sciences Company
P.O. Box 1329
Placentia, CA 92670
Attn: Dr. David L. Hench

The Optical Sciences Company
8301 Greensboro Drive
McLean, VA 22102
Attn: Dr. Thomas F. Wiener

OptiMetrics
P.O. Box 7766
Ann Arbor, MI 48107
Attn: Mr. Frederick G. Smith

Pacific-Sierra Research
Suite 1100
1401 Wilson Boulevard
Arlington, VA 22209
Attn: Dr. Ronald N. DeWitt

PhotoMetrics, Inc.
4 Arriw Drive
Woburn, MA 01801
Attn: Dr. Irving L. Kofsky

Radiation Research
3550 Hulen Street
Fort Worth, TX 76107
Attn: Dr. M.B. Wells

Rockwell International
11642 Wallingsford Road
Los Alamitos, CA 90720
Attn: Michael F. Sentovich

Industry, Continued

SRI International
333 Ravenswood Avenue
Menlo Park, CA 94061
Attn: John D. Malick
Richard H. Monahan, Room AH-157

Science Applications
505 Marquette, N.W.
Albuquerque, NM 87102
Attn: Dr. James L. Griggs, Jr.
Mr. Ronald J. Nelson

Spectral Sciences
111 South Bedford Street
Burlington, MA 01803
Attn: Dr. David C. Robertson

Systems Applied Sciences Corporation
109 Massachusetts Avenue
Lexington, MA 02173
Attn: Dr. Ralph Shapiro

Teledyne Brown
300 S. Parkman Drive
MS-19
Huntsville, AL 35807
Attn: Mr. Robert A. Pilgrim

Titan Systems
P.O. Box 12139
La Jolla, CA 92037
Attn: Jeffrey J. Puschell

Verac, Inc.
2901 Juan Tabo, N.E.
Albuquerque, NM 87112
Attn: Mr. Joel S. Davis

Visidyne
5 Corporate Place
South Bedford Street
Burlington, MA 01803
Attn: Dr. Charles H. Humphrey

OTHER

Mr. Paul Janota
One Jacob Way
Reading, MA 01867

University of California, San Diego
Vislab P-003
San Diego, CA 92023
Attn: Mr. Wayne S. Hering
Attn: Mr. Richard W. Johnson

Johns Hopkins (APL)
Johns Hopkins Road
Laurel, MD 20777
Attn: William J. Tropf

Johns Hopkins (APL)
9713 Clocktower #202
Columbia, MD 21046
Attn: Andrew N. Vavreck

IDA

Dr. Ernest Bauer
Mr. Lucien Biberman
Ms. Elizabeth Li
Dr. Hans Wolfhard

PART V

SUPPLEMENTARY COMMENTS

AFWAL/WEA

SUBJECT: Travel Report - Captain Michael D. Abel 3 JUL 1984

TO: AFWAL/AART-2

1. Activity and Place Visited: Naval Surface Weapons Center, White Oak, Maryland.

2. Departure and Return Date: 25-28 June 1984.

3. Purpose of Visit: Second Tri-Service Cloud Modeling Workshop.

4. Persons Contacted: A complete list of attendees will be published with the Workshop Proceedings. In addition to the presenters and session chairmen listed in the Agenda (Atch 1), I have made up a partial listing of attendees (Atch 2).

5. Factual Data: As stated above, the meeting agenda is given in Atch 1. There was a wide diversity of papers presented. All three Services were well represented. The work being done today seems to be sponsored by three main development efforts: space or ground based lasers, infrared search and track, and ICBM re-entry (Navy). Of course, better understanding of clouds and cloud modeling can benefit a much broader group of systems/ development efforts including CMAG, MICOS, IRST, Night-in-Weather, and HAVE LACE, just to mention a few Avionics Laboratory programs. I have some notes on all but the classified papers. Atch 3 is a very good list of Cloud Free Line-of-Sight references given out at the Workshop.

6. Conclusions: The Cloud Modeling Workshop is relatively new and there are perhaps three general areas where problems exist (as I see it): The leadership issue is probably the least troubling. A number of Navy, Army, and Air Force laboratories have supported this effort from its beginning in late 1981. Currently, most leadership is coming from the Air Force Geophysics Laboratory. Next year's workshop is being scheduled to follow the Tri-Service Transmission Conference at AFGL; however, when compared with the atmospheric transmission area, "clouds" do not have the same support and direction from the Pentagon.

The Workshop was most concerned about the money issue. A number of DoD systems are affected (but no one knows to what extent) by clouds. Unfortunately, no one wants to fund generic research in this area (it had been hoped that DARPA money would be available). There is some money to find answers to specific questions, but this limited effort may not really be enough to develop good cloud models for realistic evaluation of weapon system performance. The laboratories in the past may have taken the lead and funded such work out of their own monies, but today they are in a 'contractor-type' position; paid by specific development projects to do specific tasks. Somehow, the Workshop will have to design its efforts to work efficiently within this less than desirable financial/management framework. Finally, there is the issue of what should the Workshop be doing (besides meeting once a year)? Below are listed some tasks brought up at the meeting (which I endorse):

a. Search and document DoD user requirements. First, locate all possible customers and then rank their possible cloud questions/problems by importance using agreed upon criteria.

b. Define as best as possible the kind of cloud model(s) that is needed and the kind of data necessary to support its development and validation.

c. Survey and document existing models, data sets, and data measurement programs. Identify shortfalls based on items (a) and (b).

d. Set down standards for data measurements and archiving.

e. Promote the exchange of new data processing technologies.

7. <u>Recommendations</u>: Staffmet involvement with this Workshop can benefit many AFWAL programs including CMAG. We need to try to define the type of cloud model and data that would be most useful for our analysis needs.

8. <u>Actions to be Taken</u>: Coordinate with Mr Ron Kaehr, CMAG Program Manager, and any other interested program manager.

Michael D Abel

MICHAEL D. ABEL, Captain, USAF
Staff Meteorologist
Avionics Laboratory

3 Atch
1. Agenda
2. Some Attendees
3. CFLOS References

cc: AFWAL/AS
AFWAL/WE
AFWAL/AARF-1
AFWAL/AAX
ASD/WE

Joel S. Davis
Verac, Inc.
Albuquerque, NM

ATTACHMENT 1

COMMENTS FOR THE MINUTES: 2nd TRI-SERVICE CLOUD MODELING WORKSHOP

Much of the conversation following the formal presentations made the point that there wasn't a lot of funding available for data collection and analysis related to cloud problems, specifically for the development and validation of cloud free line-of-sight, cloud free field-of-view, and cloud free interval models. Barring a major change in policies seen to date, it is unlikely that major funding for such investigations will ever be available. Cloud analysis and, in general, weather analysis is rarely funded in isolation because, as a problem, it is not important in isolation. Rather, weather is generally one of many problems facing an end user. Thus, resources to address weather issues will typically have to be taken from the resources of some larger investigation or project. In the systems evaluations and concept analyses with which I am familiar, this typically translates into a few man months, at most, available for analyses specifically related to the weather aspects of system performance.

Given only a few man-months for specifically addressing weather issues, the scientists and analysts involved are very limited, both in time and resources, in the data and models they can run down. Unfortunately, the data bases and models needed for such analyses are in different places, typically in different media and formats, and are not well publicized. In addition, even where they are publicized, there are often no clear or convenient channels for obtaining them.

Consider the problem of developing a dynamic cloud free line-of-sight model based on available data. Ideally, such a model would, for a given type of engagement, predict dynamic cloud free line-of-sight probabilities for cloud conditions as specified in a normal weather report. One way this might be done would be to take satellite based cloud pictures with associated altitude information, digitize these pictures, determine cloud free intervals and, for a great many such pictures, in a great many such locations, for a great many types of intervals, correlate them with the weather reports at the locations measured.

This approach requires the weather reports including clouds from locations of interest: surface weather reports or the 3-D nephanalysis or RT nephanalysis. These data bases are probably among the best known of those available within the community, but learning to read them and use them is no small task. As archived, they are stored in a peculiar kind of IBM binary, no small task for most computer systems to read. The mere format of the data itself may take weeks to learn and truly understand. One must know the data is there, understand its content, discover how to procure the data, obtain the data itself, understand its format, learn to read the tapes, develop software to access data from the tapes, and interface that data with whatever software one has available for statistical analysis before one can successfully utilize this data base at all.

One's task is not yet done. There are a variety of sources of satellite pictures, each with its own organization, channels for access, storage locations, etc. The data are archived at various universities and at various government sites often controlled by NASA. To begin with, one must be aware that each of these data bases simply exists; second, one must know of their content; third, one must be aware of how to obtain the data; fourth, one must be able to either obtain the data in digitized form or be able to get this data digitized. There are, of course, organizations such as METSAT, Inc., which accomplish digitization, but it is merely another step in the process of trying to utilize the data. Only after both of these data bases are identified, obtained, read, integrated and analyzed can one begin the analyses which integrates them to begin devising a dynamic cloud free line-of-sight model. This is asking a lot for a few man-months.

Barring the discovery of the so called "sugar daddy", this working group is unlikely to be able to fund major data gathering or analyses in and of itself. However, by doing a certain amount of front end work it can open the door for many analyses to be performed by analysts on different projects for different users across the country, by making it convenient and most important, not terribly resource intensive for these analysts to obtain the data and models they need. At a minimum, I would envision this working group endeavoring to publicize as widely as possible the data and models available. It could undertake to publish, as a standard package, manuals for the different data bases, including their content, format, how they can be obtained and so forth. Similar information would be published for the models. An even better solution would be for this organization to, either directly or working with ETAC and/or the Global Weather Center, establish a central clearing house. In this case, actual copies of the models and of the data on some standard media (for example, 9-track tape) could all be obtained through the clearing house in a standard procedure.

Consider the advantages of such a scheme. By one inquiry to one well-known location, an analyst could discover the available data and models for weather-related problems. If this did not include all the resources he/she needed to address the weather aspects of the problem, at least all of the available data and models would be available with a minimum of effort.

It seems clear to me, at least, that much more could be done, given the data and models available, than is now being done. I attribute this difference to the large amount of leg work required to simply run down what's there already. By minimizing this leg work, this committee could encourage a lot more analysis, a lot more model building, and a lot more validation without having to identify major funding. The funding will already be there, in the individual projects and programs which have at least a few months to spare for weather related analysis. I strongly encourage the members of this working group to consider some way in which such a clearing house might be established.

Joel S. Davis

John Hornstein
Naval Research Laboratory
Washington, DC

9 July 1984

Dr. Ernest Bauer
Institute for Defense Analysis
1801 N. Beauregard Street
Alexandria, VA 22311

Dear Ernie,

Here are some notes and comments on the discussion session at the Second Tri-Service Cloud Modeling Workshop.

The CLOUDS Program

The CLOUDS utility package should be designed so that a particular type of output file (an analog would be a LOWTRAN transmittance file) can be produced by any of several modules providing the same types of information but with different accuracies and degrees of detail. For this, the format of a given type of output file must be essentially independent of the program that produced it. This can be accomplished by having the file contain flags to tell the next program how to read it. The file itself would consist of a sequence of "tables", such as a transmittance table, various profile tables, a table giving the irradiance for a scan across a cloudy scene, etc. The format of each type of table would be independent of the program producing it, except for the number of lines and number of digits displayed, which would be specified by an integer prolog in the table. The resulting flexibility would be valuable in two ways:

(i) - A user ccould develop an application using quickly-running low-accuracy versions of each module, and then switch to one or more higher accuracy versions for a final run, or as an inexpensive test of how much accuracy is needed for the application at hand.

(ii) - We do not yet have a clear idea of what types of output the DoD community wants. Moreover, DoD needs will continue to evolve, partly in response to experience with whatever cloud modeling capabilities are available. The table-based file structure does not force us to wait until all desired capabilities are fully specified, nor does it force us to freeze these capabilities prematurely. We can start immediately to design modules to produce some initial products - which will help in obtaining funding - and use pre- and post-processing programs to adapt this early-designed output as future needs define themselves.

What about the non-DoD user community?

Dr. Jacobowitz expressed NOAA's interest in being kept informed of DoD needs for atmospheric data. I know several NASA scientists and contractors who would have been very interested in attending the Tri-Service Workshop. They have alot to contribute: one of them (Warren Wiscombe) is world-renowned for his work on atmospheric radiative transfer, which included identifying a few parameters of a particle size distribution that dominate its scattering effects; another has unique data. There must be others at NCAR and in universities who would like to share information with us.

We could gain alot from this. Besides data, there would be items of knowledge that are difficult to acquire under the constraints of working in a mission-orientea environment. These people are also a market for our programs (witness LOWTRAN) and data, and in the course of using them they will be testing and evaluating them. They may have the opportunity to work on problems we need to have solved but cannot get funded within DoD, and can provide a constituency in other agencies for work on these problems.

This raises two obvious issues. How do we tell the wider scientific community what our problems are, without divulging sensitive information? How do we offer a quid pro quo of programs and data in exchange for their efforts and data, while reserving sensitive information? Both problems seem solvable. (i) We need a forum for explaining our needs. Since a meeting in which some sessions are closed and others are open is both cumbersome and insulting, occassional meetings should be for unclassified material only. To preserve DoD support and avoid loss of focus, these meetings should be even more narrowly oriented toward specific DoD needs than closed Tri-Service workshops, which can and should be more wide ranging. (ii) As LOWTRAN illustrates, we have models and data that can be released to the wider community without revealing sensitive aspects of the purpose or means of data collection or model development. For use as a quid pro quo, we may have to increase the volume of this material, scrutinizing the data and models we have to identify additional material that can safely be released (with proper approval, of course). To avoid embarrassment and to ensure that we have something on hand to show potential colleagues,it would be best to identify such material before we actively solicit the participation of the wider community. Should this be done individually, or should there be a DoD-wide catalog of data and other materials that can be shared? The latter option is related to the clearing-house issue, discussed next.

Validation of modules and data for CLOUDS and related programs

The discussion panel broached the possibility of an evaluation board to approve modules and data before they are accepted as full-fledged ingredients of CLOUDS or related programs. I feel that this should not mean that "public" access to a candidate module is restricted until the module has been certified. Much information on validity, utility and ease of use can be generated by early wide dissemination to users, accompanied by suitable caveats.

Who is the user community within DoD?

Stan Grigsby noted that one service we can perform is to draw up a list of applications, and for each application indicate how clouds affect it, which of these effects depend on still-unresolved cloud issues, and the plausible impact their resolution would have for that application. This list would have several uses:

- they indicate some of the capabilities that the CLOUDS package should provide, helping to define the system;

- they show the relevance to weapons effectiveness. Some needs may have such a narrow range of application that they will identify a particular sponsor, who must either fund those parts of the work or expect to see his needs unmet. (The application may be important despite being narrow.) This would be especially favorable for getting the program off the ground, since it gets around the reluctance of sponsors to fund capabilities that other people will also use. On the other hand, some needs will be relevant to so many applications that their cumulative importance will elicit funding, or provoke NASA or NCAR (NSF) or NOAA interest. As several attendees stressed, the key to DoD funding (or NASA/NCAR/NOAA activity on a problem relevant to our needs) is for the "cloud community" to push a fixed set of problems and capabilities that respond to a few identifiable and documented needs.

What person or group will start drawing up this list?

Another aspect of "What is the DoD user community?" is "short wave chauvinism". The Workshop stressed IR and optical aspects, but both designers and users of passive and active microwave systems suffer from cloud (mostly precipitation-induced) clutter and attenuation. Some of these people have considerable interest and expertise in CFLOS and cloud microphysics and dynamics. They should probably be invited to join us. Besides bringing their knowledge and data, they are a "market" for our models and data, increasing our constituency.

The Clearing-house issue

Several attendees wanted a central clearing-house for cloud data, programs and lore. The panel mentioned that it had neither funds nor a mandate for a clearing-house yet. At present it can serve only as an unofficial contact point. One attendee stressed that a great deal of time and effort could be saved if one person or group undertook to at least know the location of all data, programs and experts. ~~Someone~~

One attendee raised the related issue of efficient access for newcomers to the lore: typical microphysical and optical parameters for various types of clouds; relative importance of scattering and absorption in various spectral regions; etc. Since this material doesn't change rapidly, it doesn't seem necessary to have a person or group "on call" with this material. The need could be met by a good chapter devoted solely to clouds and fog, in something like the Handbook of Geophysics or the IR Handbook; preferably the former, since the microwave community also needs this material. The current treatments in these two books are too scanty and out of date, and neglect some important topics.

A problem with contract studies.

A final issue of access concerns DoD access to intermediate results of contract studies. Ron Nelson raised this issue, but it has also been a problem for our group. Quite often intermediate results or reasonings would be useful in themselves or for evaluating the suitability of a contract deliverable for a possible application. Attempts to obtain these final but intermediate results frequently encounter a stone wall. What is needed is not a formal report, which is troublesome and expensive, just a recognition that this material is not proprietary, and a willingness to discuss it. Perhaps the panel of the Tri-Service workshop knows a few people at appropriate levels who could insist that contract work sponsored by their commands must make their final intermediate results and methods of reasoning available - in an informal way and only on demand - to qualified requestors.

John Hornstein
Code 6521
Naval Research Laboratory
Washington, DC 20375

(202) 767-3069

cc: Donald Grantham (AFGL)
Edward Stone (NRL)

DEPARTMENT OF THE ARMY
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD., ADELPHI, MD 20783

REPLY TO
ATTENTION OF

DELHD-RT-CB 28 June 1984

SUBJECT: Suggestions to Tri-Service Cloud Modeling Committee

Commander
Air Force Geophysics Laboratory
Atmospheric Sciences Division
Tropospheric Structure Branch
ATTN: LYT/Dr. D Grantham
Hanscom Air Force Base, MA 01731

1. First, I would like to thank you and your collaborators for putting on such a fine workshop. I found it a very worthwhile experience.

2. In response to your request during the wrap-up session for written comments, I would like to endorse the suggestion by various people that a recommended program be put together now. This program should consist of high priority unfunded tasks that the committee believes are a necessary part of an overall effort that should be pursued as soon as funds become available.

3. One such task, mentioned by Dr. Ernest Bauer of IDA during the wrap-up, concerns experimental cloud edge data. The need for more such data became quite evident during the workshop. As you know, the Harry Diamond Laboratories have the measurement capability for obtaining such data, and have already obtained a significant data bank containing cloud edge data. Examples of these data were presented at the First Cloud Modeling Workshop and published in the collected viewgraphs, and more recently presented at the IRIS Targets, Backgrounds, and Discrimination Subgroup Meeting and published in its proceedings (just out). Reduction and analysis of more of these data, which are to resolutions as fine as ≈1.5 m, should significantly enhance our understanding of cloud edges.

FOR THE DIRECTOR:

Z. G. SZTANKAY
Chief, Near Millimeter
Wave Branch

PART VI

ON THE USE OF AIRBORNE LIDARS TO COLLECT METEOROLOGICAL DATA (WINDS, DENSITIES, AEROSOLS) DURING MISSILE REENTRY DURING BROAD OCEAN AREAS

(Report of a meeting on above subject, held at the Institute for Defense Analyses on 24 January 1984)

IDA
INSTITUTE FOR DEFENSE ANALYSES

SCIENCE AND TECHNOLOGY DIVISION
1801 N. Beauregard Street, Alexandria, Virginia 22311 • Telephone (703) 845-2000

25 January 1984

MEMORANDUM FOR DISTRIBUTION

SUBJECT: On the Use of Airborne Lidars to Collect Meteorological Data (Winds,Densities,Aerosols) During Missile Reentry over Broad Ocean Areas(BOA). Preliminary-for Review.

Ernest Bauer Stanley Grigsby

FROM: Ernest Bauer and LCDR Stanley Grigsby(NAVSEA)

On 24 January 1984 an unclassified meeting on the referenced subject was held at IDA. The list of attendees is included as Attachment 1.

The reason for the meeting was a response to needs by the Navy Fleet Ballistic Missile Office (SSPO) for weather measurements during RV reentry over BOA's , principally in the S.Atlantic Ocean. The problem was defined by R.Sokol (SP-27,Reentry engineer for the D-5 vehicle) and by Jay Berkowitz (SP-25, Test engineer) who stated that current primary requirements are for winds and densities at altitudes to 50/100 Kft, with less emphasis on

a. large ice crystals ($\gtrsim$ 300 μm)

b. higher altitudes (to 250-350 Kft).

Earlier concern with cirrus has been reduced by aerodynamic redesign leading to higher altitudes of transition to turbulence on the vehicle.

Lee Dickinson (LMSC) reported on the ADMSS (=Aircraft Deployed Meteorological Sounding System) study, which was conducted some two years ago by Space Data Corp. It included a review (by Kentron Corp) of indirect sensing which concluded that at the time of the study lidar and other remote systems were not suitable for gathering the necessary data, although the technology was progressing rapidly. The ADMSS study recommended using dropsondes and sounding rockets, all deployed from a P-3 aircraft. The recommendation has not been acted upon, principally because of the high risk and cost of ensuring safety for the aircraft during the rocket launches. It was stated that meteorological data are actually used in computer programs with 1000 ft. vertical resolution.

Freeman Hall (NOAA/WPL) reported on their ground-based Doppler lidar system for measuring winds; Geoff Kent (IFAORS- substituting for Pat McCormick of NASA/LaRC) reported on airborne aerosol measurements, and Tom Wilkerson (U. of Maryland) reported on the capabilities of DIAL and other lidars to measure temperature and pressure (from which density is derived).

Capt. George Fisher (USAF : BMO/WE) indicated BMO concerns and needs.

The conclusions of the group are listed in Attachment 2. They represent a consensus of these experts in the lidar area.

The following material is available from IDA on request:

Attachment 1. Attendees
2. Conclusions
3. Requirements (R.Sokol)
4. ADMSS briefing (L.Dickinson)
5. Section 4 of ADMSS report on Indirect Sensing
6. Remote wind sensing by IR Doppler lidar (F.Hall)
7. Lidar measurements of aerosols and clouds (G.Kent / NASA)
8. Atmospheric lidar (T.Wilkerson)

ATTACHMENT 1.

Attendees.

Ernie Bauer	IDA	703-845-2290
Jay B.Berkowitz	SSPO	202-697-0600
Roger Carson	NSWC/Dahlgren	703-663-8740 or 8138
Lee G. Dickinson	LMSC	408-742-4956
Capt. George F.Fisher	BMO/WE	714-382-6891
LCDR Stan Grigsby	NAVSEA/PMS-405	202-692-5626
Freeman Hall	NOAA/WPL	303-497-6312
Jerry L.Harper	Kaman Sci.Corp.	303-599-1931
Geoff S.Kent	IFAORS	804-865-0811
	(or NASA/LaRC	804-865-2065)
Susan Masters	NSWC/Dahlgren	703-663-8346
Richard Sokol	SSPO	202-697-1352
Tom Wilkerson	U. of MD.	301-454-5401

CONCLUSIONS.

A. Airborne lidar capabilities achievable within a two year time frame

1. DIAL (visible) lidar to measure temperatures (± 1-2 C) and pressures (± 0.2-0.5%) at altitudes to 20 km. Cost $M 1.5 , weight, 1500 lbs.

2. TEA (10 um) Doppler lidar to measure winds (± 1-2 m/s) at altitudes to 20 km. Cost $M2 , weight, 1000-2000 lbs.

Separate systems: each needs a highly trained, competent crew of 2-3, and a 1 - 2 ft. window .

3. For the above instruments the proof of concept has been given and no technology development is required.

4. The instruments A.1 and 2 could be mounted on existing/available aircraft such as P-3, Electra, CV-990, EC-18 (B707),

5. For instruments A.1 and A.2 one issue is reliability in operation.

6. A ground-based demonstration (at Kwajalein) might be of interest to USAF

B. On a 4-10 year time frame it is possible/probable that a single lidar system to measure temperature and pressure to 50 km and winds to 25-30 km could be developed.

C. Note:

1. Costs correspond to purchase of equipments A.1 and A.2; some can perhaps be leased.

2. Lidar measurements would be above the aircraft altitude (20 Kft for P-3, 35 Kft for EC-18)- use dropsondes below.

3. The upper altitude limit to wind measurements is set by the low aerosol density above 20-25 km, especially in volcanically quiet times.

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